HUMAN BIOLOGY

a record of research

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This special issue, edited by Josef Brožek of the Laboratory of Physiological Hygiene, University of Minnesota, is devoted to the proceedings of the Conference on the Role of Body Measurements in the Evaluation of Human Nutrition, sponsored by the Committee on Nutritional Anthropometry of the Food and Nutrition Board of the National Research Council, held at Harvard University, Cambridge, Massachusetts, June 17 and 18, 1955.

INTRODUCTION

The appearance of nutritional anthropometry is a most welcome development for physical anthropologists. Anthropometry in its early days was devoted to the comparison of races in their skeletal dimensions; it almost seemed to wish, in a perfectly humane way, of course, that all of its subjects were skeletonized, as some of them were; and its techniques were designed to render as negligible as possible individual differences in fat and muscle. The result was that anthropologists got what they wanted: data on the skeleton only, squeezing out the rest of their subject. There was evolved an advanced and competent instrumental and statistical technique which eventually outstripped the data themselves. When racial comparisons had been more or less completed, and certain studies of growth and other kinds of variation made, there was a reduced scope for the technique. Obviously the neglected area from bone to skin awaited investigation, but this was slow in coming. The influence of genetics accented blood group and other physiological work; and constitutional anthropologists, largely following Sheldon, turned attention to consideration of all the constituents of physique, not the skeleton alone, though by means of a technique which is in its nature rather specialized.

With the arrival of broader problems of nutrition and of the analysis and variation of all the constituents of physique together, the traditional methods and approach of anthropometry find their natural extension. These problems will certainly benefit anthropological techniques as much as the techniques will benefit the studies, and their mutual development represents the kind of outlook in physical anthropology which was unceasingly encouraged by Professor Hooton. It was therefore particularly fitting that the Conference on Nutritional Anthropometry should have been held at Harvard.

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RECOMMENDATIONS CONCERNING BODY MEASUREMENTS FOR THE CHARACTERIZATION OF NUTRITIONAL STATUS

FOREWORD

THE Recommendations and the articles published below are the outcome of a meeting held on June 17 and 18, 1955, by the Committee on Nutritional Anthropometry of the Food and Nutrition Board of the National Research Council. The meeting, attended by 34 invited experts and observers in addition to members of the Committee, was held in Littauer Hall in Cambridge, Massachusetts, by courtesy of Professor W. W. Howells and the Administration of Harvard University.

This was the final official activity of the committee which was established in May, 1951, in recognition of the situation indicated in a report to the Board (Minutes, Vol. 9, p. 28, May 1949):

"The need for this committee arises from the fact that the evaluation of the nutritional status of man with regard to emaciation, obesity, growth, skeletal and muscular development is a major neglected area of human nutrition. Such evaluation must depend primarily on physical measurement of the body and comparisons with suitable standards for

selected items of measurement. There are at present no well-defined uniform methods or properly characterized standards for these purposes. Common methods of physical anthropology are devised with a view to different problems. Common clinical methods are extremely crude and relatively subjective.

"For the development of this area, it is necessary to use facts and expert knowledge from several fields which do not ordinarily have contact with each other. Among these would be nutrition, physical anthropology, pediatrics, physiology, actuarial science, anatomy, physiological hygiene, and general statistics. There are at present neither national nor international organizations to consider these problems or to assemble experts from the several fields which can contribute.

"The American Medical Association, the Food and Agriculture Organization, and the World Health Organization, in addition to the Food and Nutrition Board, have recognized the need for some organization to consider these problems. There seems to be general agreement that the National Research Council would be a suitable focus for such activities and that, within the Council, the Board would be the proper sponsoring agency."

Impetus to the establishment of the Committee was given by the Second Session of the Joint FAO/WHO Expert Committee on Nutrition, in Rome, April, 1951, which stressed the relationship between bodily dimensions and nutrition and pointed to the need for anthropometric data utilizing agreed methods and standards (World Health Organization Tech. Rept. Ser. 1951, No. 44, pp. 63-64). The Fourth Session of the Joint FAO/WHO Committee again emphasized these points (W. H. O. Tech. Rept. Ser. 1955, No. 87, p. 44) and recommended "That efforts be made in the near future to assemble a study group or expert committee to consider and to report on these questions of methods, standardization of procedures and reporting, the planning of surveys, and the provision of norms, and on the whole problem of the application of anthropometry to nutritional evaluation."

At the Harvard meeting all in attendance were "co-opted" for participation in the formulation, drafting, and discussion of the Recommendations. Subsequent to the sessions at Harvard, an edited draft of the Recommendations was sent to each of the participants and to members of the Food and Nutrition Board for comment and emendation. The final draft published here embodies the responses.

Acknowledgment should be made of the contributions to the work

of the Committee by Committee members who served until 1954: Drs. Harold C. Stuart of Harvard University, Grace A. Goldsmith of Tulane University, Louis I. Dublin, formerly of the Metropolitan Life Insurance Company, N. Y., and M. W. Krogman, of the University of Pennsylvania. Important contributions were made by correspondence by Drs. J. M. Tanner, St. Thomas's Hospital, London, and G. M. Morant, R. A. F. Institute of Aviation Medicine, Farnborough, England.

Throughout the life of the Committee Dr. Josef Brožek acted as Secretary and he also edited the Recommendations and papers published here. The participants at the Harvard Meeting are listed below. Their concurrence with the Recommendations is on a personal basis and does not necessarily reflect the official views of the organizations they represent.

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GENERAL CONSIDERATIONS

Body measurements and nutritional status

The growth, weight and composition of the body depend, in part, on the supply of nutrients and may serve as a useful, though limited, criterion of one aspect of nutritional status. For individuals of a given sex and age, body weight must be evaluated with reference to skeletal size, taking into account body height and also the width of the skeletal framework. This yields an estimate of the degree of underweight or overweight of the individual. In order to properly interpret the biological significance of body weight, data must be obtained for the approximate analysis of body weight in terms of body composition. The variable showing largest individual differences is body fat. While more complex methods are available for research, measurements of the thickness of subcutaneous fat provide a valuable measure of leanness-fatness in field work and in the physician's office.

The present recommendations are concerned primarily with adults. Nevertheless, measurements considered useful in children are listed. The problems of evaluating nutritional status in children are more complex than in adults and include rates of growth and effects of sexual maturation. These matters will not be discussed in detail here but should be at least mentioned since they are important for the interpretation of bodily dimensions as criteria of nutritional status.

In order that data obtained by different observers may be comparable, the measurements should be made in a standard manner. The apparent simplicity of the measurements is deceiving. The calibration of instruments should be checked periodically.

It should be realized that anthropometric data provide only a description of man's physique. The evaluation of biological significance of the individual differences in the rates of growth, adult body size and composition must be made in reference to such criteria as performance capacity, morbidity, and mortality.

Sampling

In surveys of whole populations as well as in surveys of specific groups (*e. g.* old people, pre-school children, etc.), one should strive for results that are representative, that is, results that are free from sampling bias with respect to the characteristic studied. Special skills are often required in sampling, and it is recommended that expert statistical advice

be sought early by any group planning nutritional or anthropometric studies.

The method of sampling must take into account occupational, social and cultural characteristics of the area to be surveyed. For populations with a complex social structure, it is desirable that stratified samples be devised that reflect the composition of the population by sex, age, economic status, ethnic origin, occupation, and other factors pertient to the particular study. In less complex societies, the sampling plan would be less complicated but nevertheless crucial to the success of the study. In some circumstances it may be expedient to use the family or household as the sampling unit. Pilot studies are advisable before engaging in a mass survey.

After the sampling procedure has been devised, every effort should be made to obtain data for the entire sample. When this is not feasible, adequate information should be obtained about non-participants in order to estimate the nature and extent of the bias in the sample surveyed.

The nature of the population surveyed should always be clearly stated; some types of surveys, in particular, will be concerned with the "general" or "presumably healthy" population. Since concepts of this nature vary greatly, specific exclusions should be set forth in detail. Such exclusions should be based on, and explained on the basis of: 1) the frequency of prevalent disease states in the population or 2) specific recording of disease states present in individual cases included in the survey.

Selection of measurements

The principal aim of the application of body measurements in nutritional research and appraisal is: 1) to arrive at a relative weight of an individual, obtained as the ratio of the actual to the "standard" weight and 2) to appraise the relative fat content of the individual. Thus weight, height and a measurement of subcutaneous fat are the irreducible basic data.

In the subsequent sections recommendations are made for selection of additional measurements defining more satisfactorily the skeletal framework and the stores of subcutaneous fat. These are considered as minimal measurements for surveys. Other measurements may be useful for special purposes. When additional measurements are made, a detailed, clear description should be provided so that other investigators can reconstruct the actual procedure used by a given investigator.

Recording

The original records are the ultimate source of all information and should be made with care and accuracy. Whatever corrections are to be made, *e.g.* for the amount of clothing worn by the subject, should be made at the time of recording the weight and should be specifically indicated on the record. Preferably, the body weight should be *recorded* as nude weight and measured with minimal clothing. Samples of the weight of clothes worn should be made at intervals if weighing is done including clothes.

The precision of making and recording the measurements will vary with the purpose and circumstances under which the measurements are made. In surveys and in medical practice involving adults, readings of height to the nearest centimeter (or quarter-inch), weight to the nearest half-kilogram (or pound), and skinfolds to the nearest half-millimeter (or 1/32 inch) are adequate. In the case of children the accuracy of recording the measurements should be increased (perhaps doubled).

Ages reported by the subjects are notoriously unreliable. Every effort should be made to obtain correct ages. The day, month and year of birth or at least the month and year should be recorded. The actual age can be computed later by a clerk. In adults ages, in years, should be computed to the nearest birthday. In children year and the nearest month should be recorded.

Reporting

Preferably, the measurements should be made and reported in the metric system, in centimeters and kilograms. In countries using the English system, the data for use by laymen may be reported also in inches and pounds. As a rule, this should be an additional, not alternative, method of reporting and its usefulness would depend on the uses being made of the data.

In reporting group data, original distributions should be presented together with the descriptive statistics (means, standard deviations, etc). This is particularly essential for variables with skewed distributions for which percentiles rather than ranges based on the standard deviation (mean $\pm$ 1SD and $\pm$ 2SD) must be used. The percentiles to be used will again depend on the purpose of the norms. When gross classification is desired the 5th, 50th (median) and 95th percentiles are useful. At other times the use of quintiles (the 20, 40, 60, and 80 percentiles) is

preferable. Finally, percentiles corresponding to the limits obtained for normally distributed variates ($M \pm SD$) may be useful in some situations.

In grouping adult individuals according to age it is useful for many purposes to use a 5-year interval, preferably coinciding with the decades (25 to 29, 30 to 34, etc.). The age divisions for children are dealt with in a later section. In view of continued growth in height, at least in some populations, it is desirable to use groupings of no more than one year of age for ages below 25 years.

BODY MEASUREMENTS ON ADULTS

In different contexts—in the physician's office, in a field survey, in the laboratory—different sets of data may be utilized for the characterization of nutritional status (nutriture) with reference to body size and composition. Under emeregency conditions one may have to be satisfied simply with measurements of height and weight.

The bony dimensions are useful primarily in arriving at the individual's "standard" or "reference" body weight. A second class of measurements characterizes the individual's leanness-fatness. A third set of measurements serves to evaluate the development of musculature.

A. *Body weight* should be reported as in the nude, with an appropriate correction for clothing worn. This correction should be made at the time of measurement. The estimate should be checked from time to time by actually weighing the clothes, if standard garments are not used. Personal ornaments and accessories should be removed. It is recommended that body weight be included in every anthropometric study of human nutriture.

B. *Body dimensions*

1. *Stature* (standing height), defined as the distance from the sole of the feet to the top of the head, should be measured always without shoes. In case of necessity, the contribution of the shoes should be estimated and deducted at the time of the measurement.

Preferably, the subjects should be barefooted or in stocking feet, standing erect, with the heels and scapulae in contact with the wall or other flat vertical surface. The head should be held so that the line of sight is horizontal. The height should be determined by lowering a rectangular wooden object or other suitable guide, re-

maining in contact with the vertical measuring scale, until it makes firm contact with the scalp.

In patients who cannot readily stand, recumbent body length should be determined. For this purpose, a rigid board such as ¼″ plywood may be slipped under the patient's body, using a right-angled foot support for bringing the feet into position. If the two measurements are to be used as reference, allowance should be made for the fact that a person's recumbent length is somewhat greater than his stature. The measurement of stature or body length should be included in all assessments of human nutriture.

2. *Sitting height.* At times it may be desirable to have an indication of the proportion of the total height represented by the trunk and legs. Two measures have been used for this purpose, the sitting height and the cristal height. The relative merit of the two measurements (or the importance of the vertical partitioning of body height) is not clearly established at present. It may be noted that large fluctuations in individual body weight have surprisingly negligible effect on the sitting height.

The measurement is taken with the subject seated on a firm stool with a horizontal surface. The knees are flexed, the trunk in contact with the wall at both the scapular and sacral region. The position of the head is the same as in the measurement of standing height. The sitting height is the distance from the top surface of the stool to the top of the head.

The measurement is of secondary importance.

3. *Iliocristal height* is obtained, with the subject standing erect, as the distance from the sole of the feet to the highest point of the ilium. Adequate pressure should be exerted on the contact surface in order to minimize the effects of subcutaneous fat which may overlie the crest of the ilium. Care should be taken to maintain the hips horizontal.

This measurement is of secondary importance.

4. *Bicristal (biiliac) diameter.* The width of the pelvic girdle is obtained as the greatest distance between the lateral margins of the iliac crests. When necessary, strong pressure should be exerted on the contact surface of the calipers in order to minimize the amount of soft tissue which would otherwise be included in this measurement.

As a good measure of the laterality of the skeletal frame, this measurement is recommended as a standard item in the minimal set of anthropometric measurements. It should be used, together with stature (and additional measures of skeletal size, if available) in the estimation of the individual's standard body weight.

5. *Biacromial diameter.* This measure of the width of the shoulder girdle is determined as the distance between the most lateral margins of the acromion process of the scapulae. The subject stands erect but with shoulders relaxed.

Biacromial diameter is the second best measure of the laterality of the bony framework but it requires special care as far as the posture of the subject is concerned in order to avoid sizeable errors.

C. *Adipose tissue.* In order to interpret intelligently the biological significance of a departure of the actual weight from a standard body weight, it is necessary to estimate the relative contribution of the adipose tissue, serving as a true measure of obesity, and of musculature. Since a large amount of adipose tissue is located under the skin, the individual's leanness-fatness may be estimated by measuring the thickness of skinfolds. For purposes of order and economy, it is necessary to agree on the pressure to be exerted by the skinfold calipers and on the sites at which the skinfolds are to be measured. It has been a general experience that a pressure of about 10 gm/mm^2 is preferable to very low or very high pressures. It is recommended that this pressure be used by all investigators, irrespective of the design of the skinfold caliper. A useful size of the contact surface of the caliper lies in the neighborhood of from 20 to 40 mm^2, and depends in part on the shape of the contact surface. The skin should be lifted by grasping firmly a fold between the thumb and forefinger at about a distance of 1 cm from the site at which the skinfold is to be measured.

At present, there is a fairly unanimous agreement on the value of two sites: upper arm and scapula.

1. *Upper arm skinfold.* This site is readily accessible in individuals of both sexes and should be measured in all studies of leanness-fatness. The skinfold is located at the back of the right upper arm (over the triceps), at the level midway between the tip of the acromial process of the scapula and the tip of the elbow. The level is located with the forearm flexed at 90°. In making the skinfold

measurement, the arm should hang down freely. The skinfold is lifted parallel to the long axis of the arm.

2. *Scapular skinfold.* The skinfold measured below the tip of the right scapula provides a good characterization of the individual's overall fatness. The thickness of the subcutaneous adipose tissue is fairly homogeneous in this area and small differences in locating the site are less important than in the arm or abdominal region or chest. The scapular site should be measured whenever feasible.

D. *Muscular tissue.* Where the required facilities are available, the muscular development of an individual is best characterized in terms of the breadths of the muscular segments of soft-tissue X-rays of the limbs. Where direct anthropometric measurements must be used, the muscular development can be estimated from the limb circumferences, provided that the thickness of the subcutaneous layer is determined at the same time and, preferably, at the same level.

1. *Upper arm circumference* should be taken with the arm hanging freely, at a right angle to the long axis of arm, and at the same level as the arm skinfold measurement. The tape should be applied lightly to the skin, without deforming its contour.

BODY MEASUREMENTS ON CHILDREN

The measurements indicated here fall short of adequacy for research. They are intended primarily for use in the field. It is assumed that field workers will be aware of the qualitative (clinical) signs of nutritional debility and hypovitaminosis, that reasonable care will be taken in making the measurements, and that local practices likely to alter any measurement or combination of measurements will be recorded.

It may be useful to emphasize that not only the final stature but also the *pattern* of development (rates of growth, appearance of ossification centers) is under genetic control. Nutrition determines the extent to which the genetic potentials are achieved. During the period of growth it is more important to compare the child's weight and body dimensions with the measurements made previously on the same child than to relate the measurements to crossectional norms established for a given age.

Not all suggested measurements are equally practicable or equally informative at all ages from birth to maturity. Therefore 5 age levels are given, with a separate listing of measurements in each.

Ranking of measurements

The suggested measurements are ranked from A to E as follows:

A. Minimum list for emergency conditions
B. Should be added for survey work, except in emergencies
C. Desirable for survey work, still require little equipment
D. Desirable, but require equipment less readily available
E. Desirable, but rarely practicable in the field.

Informative value of measurements

Length measurements are concerned with: 1) total body length and 2), when crown-rump or sitting height are included, the relative contribution of trunk and legs.

Weight indicates gross body size (bulk) and gives a rough approximation of body volume.

Body circumferences and diameters indicate laterality of build, and (in early infancy) developmental status.

Leg and arm circumferences, as well as the body circumferences, indicate extent of development of the soft tissues, fat and muscle.

"Skin-folds" (*i.e.* folds of skin plus subcutaneous tissue) indicate the thickness of the subcutaneous fat, and help to differentiate fat from muscle.

Measurement by age level

At birth

A. Length (crown-heel maximum), stem length (crown-rump maximum), weight (cord drained).
B. Circumference$_1$ (head maximum), circumference$_2$ (chest maximum, mid-inspiration).
C. Diameter$_1$ (bicristal).

10 days to 1 month

A. Length, stem length, weight
B. Circumference$_1$, circumference$_2$
C. Diameter$_1$
D. Skinfold over the triceps, below scapula and on chest (along the midaxillary line at the level midway between nipples and umbilicus).

3, 6, 9 months

A. As above
B. Circumference$_{1,2}$ plus circumference$_{3,4}$ (arm and calf)
C. As above
D. As above
E. Postero-anterior X-ray film of the hand and wrist. It should include the terminal phalanges as well as the distal ends of the radius and the ulna.

1-6 years

A. Length, stem length, weight, standing length
B. As above, eliminating head circumference at 3 years
C. Diameter$_1$, diameter$_2$ (biacromial)
D. As above
E. As above

7-10 + years

A. Standing height, sitting height, weight
B. Chest, arm and calf circumferences
C. As above
D. As above
E. As above

Note: in this age level overt signs of sexual maturation or their absence should be systematically noted, since implications of all dimensions differ, for constant age, according to maturation status.

PHYSIQUE AND NUTRITIONAL STATUS OF ADULT MEN *

BY JOSEF BROŽEK

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INTRODUCTION

MAN's physique is a complex phenomenon and its characterization will depend, in a large measure, on the investigator's purpose. In this presentation we are concerned with physique in relation to nutrition (*cf.* Brožek, '53). To narrow the subject matter still further, we shall limit our attention primarily to the adult man. While "maturity," roughly corresponding to the age range from 20 to 60 years, is not a static period (Brožek, '52), the average changes in body size and composition are much less rapid and dramatic than during childhood and adolescence (Shuttleworth, '51). Some aspects of development, such as the skeletal age assessed from x-ray films of the extremities (Greulich and Pyle, '50) are by now a closed chapter. The relationship between diet and age changes in the density of bones—estimated in the living from optical density (Mack, Brown and Trapp, '49), or, in the anatomist's workshop, in terms of the ratio of calcium in a bone to its volume—are not without interest. Nevertheless, the concern of the physical anthropologist working as a member of a nutritional team is directed principally to the soft parts of the body—the skeletal musculature and, in particular, the adipose tissue.

In the animal kingdom the role of accumulated fat as nutritional reserves is clearcut, whether it is generalized or sharply localized (as in the case of the humps in Arabian and Bactrian camels or the fat-tailed

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and fat-rumped sheep of Africa and Asia). It is not certain that the steatopygia of the Hottentot of Southern Africa does not belong to the same type of adaptation to a precarious food supply. However this may be, a comparison of the size and composition of the tail of desert sheep, enlarged with fat after the rains and plentiful food supply, and devoid of fat after drought (see Wright, '54, especially Fig. 5.20) tells eloquently the story of the importance of fat reserves as a crucial facet of nutritional status (nutriture), with sheer survival as the acid test of the value of the fat depots to the organism. When we come to man, cultural factors complicate the matter in several ways.

The situation in which survival depends, in an important measure, on the portable bank of stored chemical energy are today infrequent, even though the specter of concentration camps and famished cities and whole regions is still hovering over us. The optimal size of the fat stores at different age levels is not known at the present time with the desired precision. Nevertheless, there is no doubt that the size of the fat depots, other things being equal, is a measure of the caloric balance accumulated over a period of time and thus an important aspect of nutritional status.

The methods and the attained precision of the evaluation of somatic aspects of nutriture will vary with technical facilities, and it is necessary to differentiate clearly between tools applicable to emergency situations, detailed field surveys, and systematic laboratory research. The extremes are represented by gauging deterioration of nutritional status from changes in gross body weight of a population under conditions of severe dietary stress, on the one hand, and a detailed quantitative study of changes in the amount and distribution of soft tissues, in body fluids and in mineral density of bones, on the other hand (*cf.* Keys *et al.*, '50). Here we are concerned primarily with the simpler body measurements that can be obtained in the "field." The principles a l techniques of the densitometric and hydrometric analysis of body composition were presented elsewhere (Keys and Brožek, '53, and Brožek, '54, with citation of the literature).

WEIGHT-HEIGHT INDEXES

The ratio of weight (W) to height (H) may serve as a first and very rough estimate of the amount of soft tissues in relation to the size of the skeleton. A variety of indexes relating weight and height have been proposed (*cf.* McCloy, '36, p. 14, Krogman, '41, especially p. 5 ff.), from simple W/H to ratios involving $\sqrt[3]{W}$. No attempt will

be made here to analyze in detail the merits of the different forms of the weight-height index.

At a given height, the simple ratio of weight to height (kg/cm) provides an adequate measure of body bulk in relation to body length. The difficulties begin when one is to compare individuals of different height. More importantly, weight-height indexes share the basic limitations of all procedures which consider only the height as the reference point, neglecting the vertical proportions of the body, the lateral dimensions, and the need to take into account more directly the size of the skeletal musculature.

The problem of units ("dimensions") that may be legitimately related in the form of an index is readily solved by using relative weight, *i. e.* the actual weight expressed as a percentage of a standard weight. But what constitutes a meaningful standard?

ESTIMATION OF STANDARD WEIGHT

The "standard" weight has been defined, as a rule, as the average weight of individuals of same sex, age, and height. In the United States the basic tables of standard weight, so defined, were published in 1912 (Association of Life Insurance Medical Directors, '12) and reprinted many times, with or without essentially arbitrary corrections for the weight of shoes and clothes worn by the life insurance applicants on whom the data were based.

Comparisons with fairly recent data obtained on samples of personnel of the Armed Forces (Keys and Brožek, '53, p. 253) justify the conclusion that, by and large, the 1912 standards may be used as an approximately valid reference point in terms of which individuals in the U. S. and populations throughout the world may be compared. This is not to say that a systematic survey of the current weight status of the American population is not desirable. The excellent job done by the Canadians in this field (*cf.* Pett, '55) may serve as example of a carefully planned and well executed anthropometric survey of nutritional status. Clearly, such an undertaking appears to be the responsibility of public health authorities. Interests of the insurance industry are likely to remain limited to their patrons and to conditions under which routine medical examinations of life insurance applicants are made (*cf.* Lew, '54).

An inherent limitation of the height-weight tables is that the effect

of variations in "body build" is not considered. In regard to the skeletal framework, both the vertical partitioning of the body into head plus trunk versus legs and the consideration of the lateral bony dimensions would appear relevant.

Several authors (*cf.* McCloy, '36, '38, Pryor, '40, Turner '43, Cureton, '47) have considered lateral dimensions of the skeletal framework and of limb bones in arriving at an estimate of standard weight. For the present purposes, the available literature is limited either in the selection of measurements or the character (particularly the age) of the samples or both. The importance of the vertical partitioning of the body has not been adequately examined. In some studies the lateral dimensions, especially the width of the chest, included also the subcutaneous adipose tissue, thus confusing the issue. Most of the samples were limited to young men and women (college students) and to children.

Comparison of an individual's actual weight with the weight predicted from bony measurements yields an estimate of the relative development of soft tissues. This value is of interest as a gross measure of the somatic aspect of "nutritional status." When the characterization of relative adiposity is the principal concern, the weight standards must consider both the skeletal size and the muscular development. The deviations from such a standard represent a continuum which is a good deal closer to leanness-fatness than is the case when only the bony dimensions are taken into account.

The relationship between body weight, anthropometric variables, and age were examined statistically in a group of 238 Minneapolis firemen, with the fire stations selected at random and all members at each station included in the examination. The means and standard deviations are given in table 1. The age range was 25 to 63 years, with the bulk of the sample in the decades 30 to 39 ($N = 76$) and 40 to 49 ($N = 103$). Firemen are of biomedical interest on several acounts. Most importantly, perhaps, they represent an occupational group that can be readily identified and described in terms of the mode of life, and can serve in cross-cultural population studies such as have been carried out on cooperative basis in Italy and Sweden (*cf.* Keys, Fidanza and Keys, '55).

The body measurements included standing height, as a measure of the total body length, and cristal height, as an indicator of the vertical partitioning of the body into trunk plus head versus "leg length." The lateral dimensions of the skeletal framework are represented by the bicristal and the biacromial diameters. The thickness of the limb bones

is sampled in the form of the biepicondylar width of the humerus. The diameter (D) of the upper arm, corrected for subcutaneus fat, serves as a criterion of muscularity. It was calculated from the arm circumference (C), measured mid-way between acromion and olecranon, with arm relaxed, and the skinfold (S), measured at the same level on the back of the upper arm ($D = C/\pi - S$). Clearly, the number of measurements could be substantially increased, especially as far as criteria of

TABLE 1

Basic anthropometric data on 238 Minneapolis firemen

VARIABLE	SYMBOL	MEAN	S. D.
Weight, kg	Y	81.64	9.77
Height, cm	X_1	176.80	5.82
Cristal height, cm	X_2	108.94	4.81
Bicristal diameter, cm	X_3	29.43	1.53
Biacromial diameter, cm	X_4	39.94	1.90
Biepicondylar diameter of humerus, cm	X_5	7.14	0.43
Upper arm (muscle + bone) diameter, cm	X_6	9.07	0.65
Age, years	X_7	41.6	9.1

muscularity are concerned. However, the practical demands for economy in field work served as an effective check on mensurational enthusiasm. Also, if the initial choice of variables is a happy one, in multiple regression equations the returns from increasing the number of predictors diminishes rather rapidly.

The first-order correlations are given in table 2. The multiple regression equation for estimating standard weight from bony measurements and age is given in table 3. The coefficient of multiple correlation $R = 0.6487$. Using all the 7 independent variables, we obtain the prediction equation given in table 4. When the significance of the beta coefficients in the multiple regression is tested statistically (table 5), it becomes apparent that the contribution of cristal height is negligible and its elimination (see Johnson, '49, especially p. 339) does not affect the coefficient of multiple correlation ($R = 0.772$). The beta coefficient for the biepicondylar diameter of the humerus does not reach the 5% level of significance, either when all 7 independent variables are considered or when the cristal height is eliminated. The prediction equation based

TABLE 2

Interrelations between anthropometric data on 238 Minneapolis firemen

	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Y Weight	.4765	.4304	.4918	.4095	.5082	.5899	.1213
X_1 Height		.8911	.5241	.4154	.4067	.2138	—.2094
X_2 Cr. height			.5166	.4138	.3830	.1493	—.1469
X_3 Bicr. diam.				.2882	.4710	.1585	.2370
X_4 Biacr. diam.					.3056	.2355	—.1625
X_5 Biepic. diam.						.3756	.1650
X_6 Arm. diam.							—.0984
X_7 Age							

TABLE 3

Multiple regression equation for predicting body weight ($\hat{Y}$) from bony measurements (X_1 to X_5) and age (X_7)

$$\begin{aligned}\hat{Y} = &+0.532\,X_1\\ &-0.220\,X_2\\ &+1.088\,X_3\\ &+1.114\,X_4\\ &+5.772\,X_5\\ &+0.134\,X_7\\ &-111.704\end{aligned}$$

TABLE 4

Prediction equation for body weight ($\hat{Y}$), with 7 independent variables

$$\begin{aligned}\hat{Y} = &+0.379\,X_1\\ &+0.003\,X_2\\ &+1.085\,X_3\\ &+0.837\,X_4\\ &+1.836\,X_5\\ &+6.996\,X_6\\ &+0.202\,X_7\\ &-135.995\end{aligned}$$

on standing height, bicristal and biacromial diameter, upper arm diameter calculated from the arm circumference and corrected for subcutaneous fat, and age is given in table 6. As indicated in table 7, beta

TABLE 5

t-tests of the statistical significance of the beta coefficient in multiple regression equation with 7 independent variables

VARIABLE	t
X_1, Height	2.295*
X_2, Cristal Height	0.015
X_3, Bicristal diam.	3.015**
X_4, Biacromial diam.	3.391***
X_5, Biepicond. diam. of humerus	1.525
X_6, Upper arm diam.	9.985***
X_7, Age	3.828***

Levels of significance: * $t_{0.05} = 1.960$; ** $t_{0.01} = 2.576$; *** $t_{0.001} = 3.291$.

TABLE 6

Prediction equation for body weight ($\hat{Y}$) after the elimination of X_2 (cristal height) and X_5 (biepicondylar diameter of the humerus)

$$\begin{aligned}\hat{Y} = &+0.411\,X_1\\ &+1.204\,X_3\\ &+0.885\,X_4\\ &+7.342\,X_6\\ &+0.220\,X_7\\ &-137.510\end{aligned}$$

TABLE 7

t-tests of statistical significance of the beta coefficients in multiple regression equation with 5 independent variables

VARIABLE	t
X_1, Height	4.374
X_3, Bicristal diameter	3.421
X_4, Biacromial diameter	3.619
X_6, Upper arm diameter	11.109
X_7, Age	4.252

For comparison, $t_{0.001} = 3.291$

coefficients of all 5 variables are statistically significant beyond the 0.1% level with the upper arm diameter, as a measure of muscular (and bony) development, standing out as the variable with the highest *t*-ratio.

SUBCUTANEOUS FAT

Deviations from the weight standard, defined above, may be interpreted as "purer" measures of adiposity than when skeletal width and muscularity are not considered in arriving at the standard (reference) weight.

The characterization of the individual's relative leanness-fatness may be obtained, more directly and in still more "pure" terms, on the basis of the depth of the *tela subcutanea*. It is well known that a large fraction of the total amount of adipose tissue is contained in the subcutaneous fat depot which can be characterized quantitatively by measuring the thickness of the skinfolds by calipers or by noting the layer of skin plus subcutaneous tissue in soft-tissue roentgenograms (Reynolds, '51). At present only the use of calipers comes into consideration for extensive field work, although the development of portable x-ray machines using thulium oxide or other radio-active materials as the source of x-rays (Untermayer, '54, Army Medical Research Laboratory, '55), may substantially change the situation.

Individuals vary both in the absolute thickness of the subcutaneous "fat" at a given site and in its distribution over the body surface. For characterizing the pattern of *individual fat distribution* (*cf.* Garn, '55), as a component of body form, the number of sites should be large and skinfold measurements should be supplemented by soft-tissue x-rays of those areas (such as the trochanteric region or thigh) which are not suitable for skinfold measurements but which show marked individual differences. For purposes of classifying individuals along the *leanness-fatness* continuum—in field surveys, in schools, in clinics—the goal is to select a minimum number of sites which are suitable for skinfold measurements and provide, in proper combination, the optimal measure of relative adiposity (obesity).

The selection of sites involves several considerations, such as accessibility, precision in locating the site, relative homogeneity of the layer of skin and subcutaneous fat in a given region, and validity as an index of total fat (Brožek and Keys, '51). While measurements of skinfolds have been made for some 65 years (Richer, 1890), substantial progress

in the systematic examination of the methodological matters has been made only in recent years (*cf.* Edwards, '50).

Considering all the criteria in terms of which the sites must be judged, the first prize goes unquestionably to the dorsal skinfold measured at the upper arm (over the triceps), with the skinfold parallel to the long axis of the arm. The upper-arm site has the great advantage of an almost universal accessibility in both men and women. However, the changes in the thickness of the subcutaneous fat from the elbow toward the shoulder are large and fairly rapid and if the measurement is to have meaning the location of the site must be rather precise.

The subscapular skinfold is readily measured and has the great advantage that the layer of skin plus subcutaneous tissue is fairly uniform in this region. Consequently, the demands for precision of localization are less severe than in the case of the arm.

A variety of other sites have been examined in terms of accessibility and validity. The site along the mid-axillary line, at the level of the xiphoid process appears especially advantageous (see Pascale, Grossman and Sloane, '55).

There are rapid changes in the thickness of the skinfold going horizontally from the umbilicus to the mid-axillary line as well as from the mammae toward the axillary fossa (with the arm pendant). This makes precise measurements in this region more difficult. Yet, in men, measurement of the skinfolds next to the umbilicus and to the nipple appear useful, even though at times it is impossible to lift a true "skinfold" in these areas so that fat individuals appear actually fatter. In some individuals with a "pot-belly" the maximum thickness of adipose tissue is located definitely below the level of the umbilicus and, for some purposes, the measurement of the *largest* abdominal "fold," to the right of the midline (sagittal plane), may provide useful information.

In order to make the readings comparable it is necessary to standardize not only the points on the body surface but also the pressure with which the calipers are applied. The need for constant-pressure calipers has been recognized some time ago and various experimental models were designed at the Laboratory of Physiological Hygiene, University of Minnesota, and elsewhere (Correnti, '47, Best, '54, Edwards *et al.*, '55).

It has been a general experience that a pressure of about 10 gm/mm^2 is, on several accounts, preferable to very low or to very high pressures (Brožek *et al.*, '54).

The skin should be lifted by firmly grasping the fold between the thumb and the forefinger of the left hand, about 1 cm from the site which is to be measured. It should be remembered that we wish to measure the thickness of a complete skinfold (double thickness of skin plus tela subcutanea) and should adjust accordingly the stretch of the skin enclosed between the thumb and the forefinger.

With sites and pressure standardized, normative data will accumulate rapidly. The raw data should be reported, preferably, in the form of actual distributions. Such data are given in table 8 for 238 adult men (members of the Minneapolis Fire Department). From the distributions norms can be calculated rapidly according to one's particular needs. With the skinfold distributions typically skewed to the right, centiles provide the simplest means for defining an individual's position along these continua.

The actual centiles, selected as normative reference points, will vary according to the investigator's or clinician's needs. When we draw an individual's "profile," including not only subcutaneous fat but also criteria of general size and of muscular and bony development, dividing the distribution into 10 units may be preferable (deciles). For grouping individuals into average, lean and fat, and very lean and very fat the 5th, 20th, 50th, 80th, and 95th centiles would be more useful than deciles. Such values, derived from distributions described in table 7, are given in table 8.

A tendency toward increased fat deposition with age and some changes in the distribution of subcutaneous fat are well known facts (Škerlj, Brožek and Hunt, '53). In the present sample there is a low but statistically significant correlation ($r = 0.276$) between age and the combined skinfold thickness. Consequently, norms derived from samples with narrower age ranges will provide a more precise framework for evaluating an adult individual's leanness-fatness. For other purposes the use of norms obtained for "healthy normal young men" can be justified. The purpose of this comment is to warn against blind use of *any* set of norms.

Among Minnesota firemen, for example, men with arm skinfolds of 9 mm or less thickness are definitely on the thin side; only one of five is so thin. But as shown in table 10, the norm for thinness would be differently placed in other population samples, even if care is taken to consider only clinically healthy men of given age.

Various procedures can be used for combining several skinfold measurements into a single index of leanness-fatness. Numerically, the

TABLE 8

Distribution of skinfolds in a group of 238 middle-aged men

UPPER ARM				SUBSCAPULAR				ARM PLUS SUBSCAPULAR			
INTERVAL	*f*	Σf	$\Sigma f\%$	INTERVAL	*f*	Σf	$\Sigma f\%$	INTERVAL	*f*	Σf	$\Sigma f\%$
4.0– 5.4	3	3	1.26	6.0– 8.4	12	12	5.04	11.0–15.9	11	11	4.62
5.5– 6.9	9	12	5.04	8.5–10.9	28	40	16.81	16.0–20.9	36	47	19.75
7.0– 8.4	27	39	16.39	11.0–13.4	41	81	34.03	21.0–25.9	45	92	38.66
8.5– 9.9	24	63	26.47	13.5–15.9	30	111	46.64	26.0–30.9	44	136	57.14
10.0–11.4	39	102	42.86	16.0–18.4	30	141	59.24	31.0–35.9	33	169	71.01
11.5–12.9	31	133	55.88	18.5–20.9	26	167	70.17	36.0–40.9	28	197	82.77
13.0–14.4	33	166	69.75	21.0–23.4	26	193	81.09	41.0–45.9	20	217	91.18
14.5–15.9	19	185	77.73	23.5–25.9	12	205	86.13	46.0–50.9	9	226	94.96
16.0–17.4	22	207	86.97	26.0–28.4	8	213	89.50	51.0–55.9	8	234	98.32
17.5–18.9	12	219	92.02	28.5–30.9	7	220	92.44	56.0–60.9	3	237	99.58
19.0–20.4	13	232	97.48	31.0–33.4	7	227	95.38	61.0–65.9	1	238	100.00
20.5–21.9	2	234	98.32	33.5–35.9	3	230	96.64				
22.0–23.4	4	238	100.00	36.0–38.4	4	234	98.32				
				38.5–40.9	3	237	99.58				
				41.0–43.4	0	237	99.58				
				43.5–45.9	0	237	99.58				
				46.0–48.4	1	238	100.00				

simplest approach is to add the skinfolds and obtain normative values based on the distribution of the added measurements. This was done for the upper arm and subscapular skinfolds in tables 8 and 9. When a larger number of sites has been used, the regression coefficients in a multiple regression equation provide a measure of the relative importance of specific sites in arriving at an overall estimate of leanness-fatness,

TABLE 9

Skinfold norms based on Minneapolis firemen (N = 238, mean age 41.6 years, range 25 to 63 years). Skinfolds were obtained with a pressure of 10 gm/mm square of the contact surface. The values were rounded to the nearest 0.5 mm

	CENTILE				
SKINFOLD	5TH	20TH	50TH	80TH	95TH
Upper arm	7.0	9.0	12.5	16.5	20.0
Subscapular	8.5	11.5	16.5	23.0	33.0
Arm plus subscapular	16.0	21.0	29.0	40.0	51.0

TABLE 10

Percentage of clinically healthy employed men who have arm skinfolds of 9 mm or less in thickness. The data on Cape Town (South Africa) and Sardinian samples were provided by Dr. A. Keys

	AGE			
NO. OF MEN	Mean	Range	GROUP	%
238	42	25–63	Minnesota Firemen	20
67	47	40–55	Cape Town Whites	19
93	47	40–55	Cape Town Coloured	56
113	47	40–55	Cape Town Bantu	60
97	43	30–60	Sardinian Police	51

using body density as a criterion of leanness-fatness. It is a distinct advantage of multiple regression analysis that it provides means for reducing the number of variables (skinfolds) to the most economic number. Where an external criterion (such as body density) is lacking, the technique of factor analysis (see Chen, '53) represents a useful tool of statistical analysis and economic description of fatness as an important component of man's physique and nutritional status.

COMMENT

In the sample of Minneapolis firemen, the combined measures of the bony and muscular development and of age accounted for about 60% of the interindividual variance in body weight ($R^2 = 0.5959$ for 7 independent variables, and $R^2 = 0.5918$ for 5 predictors of body weight). By comparison, the coefficient of determination for height, $r^2 = 0.2271$. For the corrected upper arm circumference, which is the best single predictor of weight, $r^2 = 0.3479$. Clearly, the gain from combining the measurements, together with age, is sizeable and $\hat{Y}$, the predicted weight, is a good deal more precise and biologically meaningful standard than can be obtained from the traditional height-weight tables.

However, the remaining limitations should be recognized. Firstly, there are the limitations inherent in the sample itself. Secondly, perhaps a better choice of the predictors of weight could be made. Certainly, the number of variables could be increased. Instead of calculating an approximate diameter of the arm, it might be preferable to actually measure the total external diameter of the arm and deduct one-half of the skinfold over the biceps and the triceps. In the present study only the dorsal skinfold (over the triceps) was measured.

While the weight "standards," derived in the way described in the body of the paper, represent a substantial improvement in the anthropometric description of nutritional status, there remains—as a part of the standard error of estimate—the components contributed by the unaccounted variation in the size of the skeletal musculature, in the density of the skeleton, and the size of viscera. The contribution of these components in a multiple regression equation is likely to be small. The fact is that at present it is unknown.

Last but not least, we deal here only with descriptive standards. The overwhelming bulk of the data on the significance of individual variations in physique, represented by the insurance data on mortality, is limited to variations of weight at different heights (Armstrong *et al.*, '51).

As in all descriptive standard, age is "built" into these reference values. However, it may be desirable (*cf.* Metropolitan Life Insurance Co., '42), to set the value of age at the level of "young adult," perhaps at 30 years. In table 6 this would simply reduce the value of the intercept ($-137.510 + 0.220 \times 30 = -130.910$), leaving 4 independent variables (height, the two lateral diameters, and the corrected arm diameter). However, should such an "absolute" standard be desired,

the calculation of the prediction equation from a sample with a narrow age range, centering at the specified age (*e.g.* 30 years), might be preferable.

The thickness of skinfolds is a simpler and a more direct measure of leanness-fatness than standard (reference) weight. The measurement itself is fairly simple even though the procedure must be standardized—in terms of precise location, firm pressure exerted on the skinfold by the fingers in lifting the skinfold, constant distance between the spot at which the skinfold is lifted and at which the calipers are applied, constant pressure of the calipers—if the values are to be comparable from individual to individual and from group to group. A systematic use of skinfold measurements will unquestionably increase the contribution of anthropometry to the study of nutrition.

However, the matter of skinfolds and fatness is not as simple as it might appear at first sight. Some of the problems, such as the apparently differential rate of increase of the external (subcutaneous) and the internal fat, were noted elsewhere (Brožek, '55). The selection of the skinfold sites for field work involves a compromise between the several criteria of "desirability," such as accessibility and validity, as gauged from correlations with body density, an index of total body fat. Thus the chest skinfold, measured in the juxta-nipple position, has shown repeatedly a high validity for normal young men (Brožek and Keys, '51; Pascale, Grossman and Sloane, '55). Yet, the steep gradient of the subcutaneous layer in this region may make the use of the site of dubious value in other hands. In any case, it can not be used in studies including older girls and women.

A point requiring additional thought concerns the use of absolute vs. relative skinfolds, calculated as an index in which the skinfold thickness is related to total body length or to the length of a body segment (*e.g.* upper arm skinfold and the length of the upper arm). The fact is that absolute skinfolds, in reasonably homogeneous age groups, show no relationship to body length. Thus in a sample of 179 Minneapolis firemen, 30 to 49 years old, the correlations between height and the arm skinfold, the subscapular skinfold, and the combined (total) skinfold thickness yielded *r*'s of 0.022, 0.005, and 0.012, *i.e.* the two aspects of the body are independent. On the average, in the given sample the short men and the tall men have skinfolds of about the same thickness, and a single set of norms would appear satisfactory. On the other hand, in relative terms (Skinfold/Height) the taller men would be thinner.

SUMMARY AND CONCLUSIONS

"Nutritional status" (nutriture) has several facets, described in terms of clinical examination, laboratory (biochemical) analyses, and measurements of body size and body composition. It has been recognized and reemphasized more recently by the Joint FAO/WHO Expert Committee on Nutrition ('51, '55) that anthropometry provides important, though limited, tools for the assessment of nutritional status. It was noted that the physical dimensions of the body depend, in part, on the individual's nutritional history. The need for objective specification of body or skeletal "types" in the assessment of body weight was pointed out. Among the anthropometric measurements useful for throwing light on the nutritional state the importance of skinfold thickness was underlined. The thickness of the subcutaneous fat layer, whether measured by the skinfold caliper or on suitable roentgenograms, was considered to provide a more satisfactory index of relative fatness and nutritional status than the body weight. Finally, the means of estimating muscular development of an individual from combined measurements of the circumference of the extremities and the subcutaneous fat thickness were noted.

In the present study these problems were considered on the basis of empirical data obtained on 238 members of the Minneapolis Fire Department.

Height (1), cristal height (2), bicristal (3) and biacromial (4, diameter, the distance between the epicondyles of the humerus (5), the diameter of the upper arm less the skin and subcutaneous adipose tissue (6), and age (7) were used as predictors of body weight. The multiple $R = 0.770$. Eliminating two variables (2, 5) which did not contribute significantly, $R = 0.769$.

The deviations from such a weight standard, expressed in kg or as a ratio of the actual to standard weight, can serve as a substantially improved measure of adiposity. By constrast, the individual's deviations from the standard, obtained by using the traditional height-weight tables, are complex values in which the contributions of the variations in body build, especially in the lateral size of the skeletal framework, muscular development, and adiposity are not separated.

The problem of adiposity can be approached more directly by measuring skinfolds. The questions of standardization were examined and preliminary descriptive norms for adult men were provided.

Some of the unsolved problems, both at the level of anthropometric description and biological interpretation of individual differences in nutritional status, were noted.

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BODY BUILD AND BODY WEIGHT IN 25-YEAR-OLD ARMY MEN

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THE variability of body weight and its general relationship with stature is a familiar phenomenon in human biology. However, the problem of the effect of the size of the frame upon variability in body weight among men of the same stature is one which certainly merits further examination. The following material represents an attempt to investigate this question by considering the factor of laterality in body build.

The basic material utilized in this analysis was taken from anthropometric data collected by the U. S. Army Quartermaster Corps in 1946. At that time, body measurements were obtained on approximately 85,000 soldiers who were being separated from the Army during the demobilization process.

In order to eliminate the variability of weight with age, the sample was limited to men in the 25-year-old group. A series of approximately 3550 American-born White males was available for this analysis. The data actually utilized, however, were based on a series of approximately 3650 men. Body weights in this series are nude weights; stature was taken without shoes, and the body measurements were taken without clothing.

In this group, the total range of stature is from 59 to 77 inches; owing to small numbers of men at the extremes, a stature range of from 62 to 75 inches was selected for analysis. Body weight in this group varies between 100 and 270 pounds. The frequency distribution of stature in the series is normal, while the frequency distribution of weight shows the characteristic skewness to the right. Mean stature for this group is 68.6 inches, with a standard deviation of 2.4 inches,

while mean weight is 157.0 pounds with a standard deviation of 20.7 pounds. The coefficient of correlation between stature and weight is +.451.

The available anthropometric data include several body diameters, as well as circumferences. Since it was felt that a diameter would offer a better measurement of laterality than a circumference, bi-deltoid, chest breadth, chest depth, and bi-iliac diameters were selected for consideration. Of these, the chest breadth and bi-iliac diameters seemed to offer the most promise since they are diameters taken between points on the bony framework of the body and are affected less by intervening fat. These two diameters were taken with an anthropometer, with pressure being applied.

A bi-variate distribution of stature and chest breadth diameter was then prepared. Mean chest breadth for this series is 11.2 inches, with a standard deviation of .8 inches, while the coefficient of correlation with stature is +.271. A regression line, derived from the regression equation of chest breadth on stature was plotted on the bi-variate chart. With this regression line as a base, the frequency distribution of chest breadth was divided into three groups by utilizing the probable error of the regression. These three groups may be taken to represent men with small, medium, and large chest breadths in a 25, 50, and 25% ratio.

The mean body weight was then calculated for the small, medium, and large chest breadth groups for each inch of stature. There was considerable variation in these means of body weight; the medians showed even more variability. In an attempt to reduce some of this variability, separate bi-variate distributions of stature and weight were prepared for the small, medium, and large chest breadth groupings. Values for weight calculated from the regression equation of weight on stature for the three groupings of chest breadth are belived to be more consistent and reliable than the simple means.

A similar analysis was carried out with the data for stature and bi-iliac diameter. The mean bi-iliac diameter for this series is 11.4 inches, with a standard deviation of .8 inches, and the coefficient of correlation with stature is +.336, slightly higher than that of chest breadth. As in the case of chest breadth, values of weight for groups of small, medium and large bi-iliac diameters for each inch of stature were obtained.

The results from these two analyses are shown in table 1. This table gives 6 mean weights for each inch of stature between 60 and 78 inches;

one for each group representing small, medium, and large chest breadths, and similarly one for each group representing small, medium, and large bi-iliac diameters. Since the analyses were based upon stature data between 62 and 75 inches, the weight values for 60, 61, 76, 77 and 78 inches of stature have been extrapolated. The limits of the chest

TABLE 1

Mean weights of 25-year-old army men (pounds)

STATURE (inches)	CHEST BREADTH			BI-ILIAC DIAMETER		
	Small	Medium	Large	Small	Medium	Large
60	115	127	141	121	125	136
61	118	130	145	124	129	140
62	122	134	148	127	132	144
63	125	137	152	130	136	147
64	128	141	156	133	139	151
65	132	144	160	136	143	155
66	135	148	163	140	147	159
67	138	151	167	143	150	162
68	142	154	171	146	154	166
69	145	158	174	149	157	170
70	148	161	178	152	161	173
71	152	165	182	155	164	177
72	155	168	185	158	168	181
73	158	172	189	162	171	184
74	162	175	193	165	175	188
75	165	179	197	168	179	192
76	168	182	200	171	182	196
77	172	186	204	174	186	199
78	175	189	208	177	189	203

breadth groupings for 60 inches of stature are: small, below 10.0 inches; medium, 10.0 to 11.0 inches; and large, above 11.0 inches of chest breadth. At 78 inches of stature, the limits are: small, below 11.5 inches; medium, 11.5 to 12.5 inches; and large, above 12.5 inches. Similarly the limits of the bi-iliac groupings for 60 inches of stature are: small, below 9.9 inches; medium, 9.9 to 11.0 inches; and large, above 11.0 inches, while at 78 inches of stature, the limits are: small, below 11.9 inches; medium, 11.9 to 13.0 inches; and large, above 13.0 inches.

For many years, tables of "ideal" or "desirable" weights have been published by insurance companies, based upon medico-actuarial studies of large series of insured individuals. A table of this type, published

by the Metropolitan Life Insurance Company of New York, is entitled, *Desirable Weights for Men age 25 or Over.* This table represents minimum and maximum weights for men with small, medium, or large frames, for each inch of height between 62 and 75 inches. The range of weight for each inch of stature and each type of frame is approximately 10 or 12 pounds. In this table, weights are given "as ordinarily dressed," and heights are given "with shoes." The small, medium, and large frame categories are not defined.

The Army data indicate slightly higher weights for men with small bi-iliac diameters than for men with small chest breadths; in the medium body build group, weights are virtually the same for chest breadth and bi-iliac diameter; while in the third group, weights are higher for men with large chest breadths than for men with large bi-iliac diameters. The maximum figures for weight in the small, medium and large frame categories of the Metropolitan table come close, in general, to the mean weights based upon the bi-iliac diameter of the 25-year-old Army men. In any case, the area bounded by the lower and upper limits of weight in the Metropolitan table fell within limits indicated by lines representing one probable error above and below the line of mean weights, based upon either chest breadth or bi-iliac diameter.

In addition to the investigation of the effect of laterality on body weight, involving chest breadth and bi-iliac diameter, another phase of the present study consisted of a similar analysis based upon trunk height. The trunk measurement is essentially sitting height less the head and neck, and represents the length of the trunk or torso of the body. In the present series, mean trunk height is 23.1 inches, with a standard deviation of 1.1 inches, and the coefficient of correlation with stature is +.602. The same procedure as described above was followed for the analysis of trunk height, with the following results. Owing to the comparatively high positive correlation between trunk height and stature, the three groupings of trunk height, through use of the probable error of the regression, were not nearly as well-defined as in the case of the diameters. The mean weights which were then calculated for the small, medium, and large trunk height groups were also quite irregular. It may be concluded, therefore, that a preliminary investigation of the relationship between trunk height and stature indicated that a length measurement, such as trunk height, is not as satisfactory for the consideration of variability in body weight as is a diameter.

In summary, an analysis of weight and body build was carried out

on a series of approximately 3550 25-year-old White Army separatees. For each inch of stature, mean weights are presented for small, medium, and large groupings of chest breadth and bi-iliac diameter.

The material presented in this paper represents only a preliminary investigation of the problem of laterality in body build. However, the weights presented in table 1 are those for definite categories of body size as determined by the use of chest breadth and bi-iliac diameters.

The weights shown in the Metropolitan Life Insurance table, although they approximate fairly closely the Army values, are for categories of body size in which the determination of the size of the frame is not specified or defined in terms of any body diameter.

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VARIABLE FACTORS IN SKELETON WEIGHT

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"THE skeleton is a living and not an inert tissue. New bone is constantly being formed and bone is ever being resorbed, not necessarily at the same rates in all bones or even in any one area of a given bone" (Howard, '51). However, it is believed that the skeleton changes less in weight than do other components of the body when there is either a marked increase or decrease in total body wight.

In the field of nutrition it is desired to know the contribution made by the skeleton to total body weight. It was assumed in 1950 by the authors (Keys *et al.*) of *The Biology of Human Starvation* "that on the average 16% of the body mass is normally provided by the bones." Of the three individual determinations cited, the lowest was 14.8% found by Mitchell *et al.* in 1945. In 1953 another body was analyzed in Mitchell's laboratory and its skeleton weight in per cent of total body weight was 17.6%, matching exactly the average arrived at by Wilmer in 1940 from a search of the literature. These scant data support the premise that the weight of the skeleton is relatively stable in its relationship to the body as a whole.

Matiegka had proposed in 1921 that the weight of the skeleton in the living could be estimated from a formula based on certain measurements. These are stature (S) and the maximum transverse diameter of the lower end of arm, forearm, thigh and leg ($4TD$). The indicated sites for measurement are bony prominences which are relatively free from overlying soft parts. The formula is:

$$\text{Stature, cm} \times (\text{average } 4TD, \text{cm})^2 \times k_1 = \text{Skeleton weight, gm.}$$

The coefficient, k_1, which is still to be determined but was believed to be from 1.0 to 1.2, was recommended to "equalize all arisen errors."

Recently Matiegka's formula was tested on a series of 24 White male skeletons in the Terry Collection with an age range from 18 to 87 years (Trotter, '54). The skeletons were selected for completeness and age with 3 or 4 in each decade. The statures of the cadavers from which the skeletons came were known, but the transverse diameters were taken on the bones directly rather than before skeletonization. It was found that the independent variables, stature and the transverse diameters, involved in Matiegka's formula have a statistically significant multiple correlation coefficient with the dependent variable, total skeleton weight; it is .7362 with a probability of $<.001$ and a standard error of estimate of 567 gm. It should be noted that this probability was erroneously reported as $<.01$ in the previous publication.

In an attempt to find other variables which are now highly correlated with skeleton weight or which may have a bearing on this problem it was discovered that:

age is not significantly correlated with skeleton weight;

stature has a correlation coefficient with skeleton weight of .6909 with a probability of $<.001$; and

femur weight has a correlation coefficient with skeleton weight of .9591 with a probability of $<.001$.

Since the weight of the femur, or rather the average weight of the pair of femurs, has such a high correlation coefficient with the total skeleton weight, certain other factors concerning the femur, which could be determined in the living subject, were tested. These include average maximum length of a pair of femurs, average bi-epicondylar diameter, sum of the outline areas of photographs of actual size taken from an anterior view and, finally, sum of areas of compact bone in the middle half of the femurs shown by X-ray, taken with the tube six feet from the film, postero-anterior view. The areas were measured with a planimeter. The tests show that:

femur length has a correlation coefficient with skeleton weight of .5833 with a probability of $<.01$;

bi-epicondylar diameter has a correlation coefficient with skeleton weight of .5344 with a probability of $<.01$;

area of femurs has a correlation coefficient with skeleton weight of .7159 with a probability of $<.001$; and

area of compact bone has a correlation coefficient with skeleton weight of .7634 with a probability of $<.001$.

The femur is the longest bone in the body and the heaviest single bone. The skull is heavier and may be considered as a unit since only the mandible is a separate bone. The hip bone, largely cancellous, is also relatively heavy, although not as heavy as either femur or skull. Because of Matiegka's suggestion that diameters of limb bones are indicative of the weight of the skeleton, the greatest breadth of the pelvis and the greatest antero-posterior and transverse diameters of the skull were tested, also. The indication of correlation between either of these diameters or of the weight of the hip bone with weight of the total skeleton was not sufficient to warrant further study.

These findings show that the configuration of the internal structure of bone is a more significant factor than either size or age in determining its weight. In long limb bones is found a greater proportion of compact (*substantia compacta*) to cancellous or spongy (*substantia spongiosa*) bone than in other bones excluding the skull. When the balance between resorption and formation of bone in an adult is lost and resorption becomes greater than formation it is the cancellous bone which is reduced first. Experimental studies on rat femurs, for example, have shown that the cancellous bone was reduced after a period of low calcium intake; when the period was extended and the intake was less, the reduction included the internal portion of the compact bone (Ellinger, Duckworth, Dalgarno, '52). The comprehensive work by Amprino and Bairati ('36) includes a survey of the compact bone of the femoral diaphysis of 94 individuals from 8 months prenatal to 94 years of age. They found that this imbalance between resorption and formation occurs in man after middle life. The process of resorption of the internal wall of the diaphysis is no longer compensated for by redeposition, so that a spongy stratum of bone occupies the area which has been the most internal portion of the compact substance.

Does this process of change and reduction of the internal architecture of the femur occur in all bones of the skeleton? And, what change, if any, occurs in the chemical composition of bone? For the most part, analyses of bones, both animal and human, have been made on small samples of a particular bone, and most often of a selected long limb bone. The evidence found has been extrapolated to include not only the entire bone, but, also, the entire skeleton. In 1953, after analyzing the second cadaver, Mitchell and his co-workers at the University of Illinois concluded that a single bone is not likely to give a true estimate of the composition of the entire skeleton. For each cadaver, they had

analyzed three bones separately, the remaining bones of each skeleton were mixed and samples only were studied.

A dry, fat-free bone is composed of organic and inorganic matter. Whole human bones may be rendered dry and fat-free, weighed, ashed, and weighed again. The difference between the weight of the ash and the weight of the dry, fat-free bone before ashing is the weight of the organic component. In our laboratory the individual bones (with few exceptions) of 7 male skeletons from one Negro and 6 White cadavers ranging in age from 45 to 89 years have been so treated (Trotter and Peterson, '55). In addition, the long limb bones of 10 more White male cadavers were ashed. The weight of the ash of each bone was reduced to a percentage of its dry, fat-free weight.

The average percentage ash weights of the long limb bones of 16, or, of all but one, of these cadavers show only small differences (table 1). The long limb bones of this one cadaver are not included in these averages because the percentage ash weights are so much lower than in the others. This reduction in percentage ash weight was found in most of the bones of this skeleton as will be shown later.

TABLE 1

Average of ash weights in per cent of dry, fat-free weights of long limb bones from 16 cadavers

BONE	AVERAGE	RANGE
Femur	66.5	65.0–68.1
Tibia	66.5	63.4–68.5
Fibula	66.9	62.8–69.2
Humerus	66.6	63.2–68.9
Radius	67.0	63.2–69.5
Ulna	67.2	64.4–69.6

When the averages of the percentage ash weights of these bones from the 8 cadavers 60 years and less are compared with those of the 8 cadavers over 60 years of age it is found that each bone of the younger group shows a slightly higher percentage than its counterpart in the older group. However, the average percentage ash weight of the bones of the younger group is only 0.5% higher than of the older group and a much larger series is needed in order to test its significance. A more pertinent test would be a comparison of this older group with cadavers in the third decade of life.

The percentage ash weights of the 7 complete skeletons (table 2) are quite uniform with the exception of the 65 year old. This skeleton has a percentage ash weight of 54.5%, from 10 to 12% lower than any one of the other 6, which range from 64.8% to 66.9.%

The percentage ash weights of most of the individual bones comprising each skeleton vary less than 5% from the percentage ash weight of the complete skeleton. In the 60 and 72 year old skeletons, there are no bones which vary as much as 5%. In the 89 year old, only the left patella has a percentage ash weight which is more than 5% below

TABLE 2

Ash weight in per cent of dry, fat-free weight of complete skeletons and range among individual bones of each

AGE (YEARS)	COMPLETE SKELETON	RANGE AMONG BONES
45	65.2	57.6–69.7
56	65.3	55.2–69.0
60	66.9	63.7–68.4
65	54.5	28.7–71.3
72	65.6	63.3–68.5
73	64.8	53.4–69.9
89	64.9	49.2–69.8

that of the total skeleton. In the 45 and 56 year old skeletons there are three bones in each with low percentage ash weights; for the former: sacrum, right clavicle and right hip bone, and for the latter: sternum, sacrum and left hip bone. (The bone with the lowest percentage ash weight is given first and the others in order of increasing value.) In the 73 year old skeleton the percentage ash weight of the sternum and sacrum are each approximately 10% below that of the complete skeleton; the vertebrae (excluding the cervical) are equally low and the left and right ribs, 6% and 8%, respectively. The bones of the 65 year old skeleton which have percentage ash weights as much as 5%, or more, below that of the total skeleton are sacrum, sternum, and both hip bones, in that order, then vertebrae, right clavicle, ribs, ulnae, radii, and right fibula. Thus, it appears that when a reduction in percentage ash weight of a skeleton takes place, it occurs first in bones which are largely cancellous. As the amount of reduction increases, it is extended also to include long limb bones which have a greater proportion of compact substance. The percentage ash weights of the cranium and mandible

are consistently high. In 5 skeletons, the mandible has the highest percentage ash weight; in one it is exceeded by the vertebrae and in another by the left radius. The presence of teeth does not seem to increase the percentage ash weight. The differences between the highest and lowest percentage ash weights among the bones of each skeleton range from 4.7 in the 60 year old to 42.6 in the 65 year old.

It is of interest to compare the percentage ash weights found in the two skeletons at the University of Illinois with those at Washington University (table 3).

TABLE 3

Ash weight in per cent of dry, fat-free weight of bones at the University of Illinois and at Washington University

AGE (years)	BONE Tibia	Ulna	Rib	Total skeleton
		University of Illinois		
35	66.3	64.0	57.5	56.7
46	69.3	65.6	62.1	56.9
		Washington University		
65	55.9	48.0	44.8	54.5
(6 others)				
45–89	66.7	67.3	63.1	65.5

The 65 year old skeleton at Washington University has a total percentage ash weight which differs from the skeletons at Illinois by less than 3%, but the tibia, ulna and rib percentages are considerably lower. Conversely, the other 6 skeletons at Washington University have total percentage ash weights which are considerably higher than the skeletons at Illinois, but the tibia and ulna percentages are approximately the same. In each of the 7 skeletons studied at Washington University the total percentage ash weight matched rather closely that of the long limb bones, but for both skeletons at Illinois the total percentage ash weights were considerably lower than those of the long limb bones. It is suggested that this discrepancy between results from the two laboratories may be explained by the fact that at Illinois except for two long limb bones and one rib of each skeleton which were studied in their entirety, a sampling technique was utilized for the remaining bones of the skeletons.

From the evidence provided by these studies it is indicated that the process of metabolism in the adult does not invariably maintain equilibrium between the organic and inorganic components of the skeleton, and further, that such imbalance is not uniform among the individual bones, but rather a progressive change which is initiated in one region and extended to other regions in an orderly sequence.

It is suggested that the term "demineralization" be limited in its usage to signify a reduction in the proportion of the inorganic component to the organic component of a bone, and not to signify a degree of atrophy in which there is a comparable reduction of both components in proportion to the size of the bone. As an example, imbalance between the components is present in osteomalacia through failure of calcification of newly deposited osteoid matrix, whereas balance between the components is maintained in osteoporosis even though there may be a marked degree of atrophy.

Since the size of a bone is one of the variable factors contributing to its weight a more critical determination of this factor than straight-line measurements is indicated. A measure of the volume enclosed within the surface of the bone might be useful in evaluating its weight. Determination of the relationship between volume and weight of each bone of an adequate series of complete skeletons with a wide age range would provide evidence of either uniformity and/or variance in weight per unit volume of the same bone of different skeletons. On the same series of skeletons the actual amounts of the organic and inorganic components should be found, in addition to the proportion of these components to each other. It would be interesting, also, to explore the degree of correlation between the weight/volume ratio of the bones and their "densities," determined from X-rays.

In summary, there has been presented:

an analysis of the degree of correlation between age, stature and certain diameters of the skeleton and weight of the skeleton;

evidence that the internal structure of the femur is more highly correlated with weight of the skeleton than diameters;

data which show that the ratio between the organic and inorganic components of the skeleton is usually constant among the individual bones, but that in some skeletons the inorganic components may be reduced, first in bones which are largely cancellous and later in long limb bones which have a greater proportion of compact substance.

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SKINFOLD MEASUREMENTS IN YOUNG AMERICAN MALES

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INTRODUCTION

THE growing use of skinfold measurements obtained with constant-pressure calipers has emphasized the need for large-scale surveys of selected populations to develop standards against which future studies can be compared. No single survey will be adequate in this field, even within one population, because age (Brožek, '52), sex (Škerlj, Brožek, and Hunt, '53), and physical activity differences (Brožek, '54) will require subsampling beyond the capacity of most surveys. This report is not definitive, even in its selected sample of young American adult males, but it should provide data more extensive than presently available.

The sample reported here consists of approximately 2,400 young men measured shortly after induction into the U. S. Army and before the start of basic training. Two thousand of these were re-measured after 6 or 7 weeks of training and an analysis of the changes which occurred in these men will be reported later. The series used here consists of 2,017 American-born White males and 361 American Negro males. Certain comparisons between these racial groups have been published (Newman, '55). It was concluded that no great error was introduced by using the same regression equation for converting skinfold measurements to body fat although the original equation was based solely on White college students.

This report will cover two aspects of the skinfold measurements obtained on these men. One, the basic statistics on the measurements will be presented for the use of other workers in the field. Two, geographical and racial groups will be contrasted to show interesting differences between regional subsamples.

The measurements were collected at 7 Army basic-training centers in the eastern and southern portions of the country, from Maryland to Arkansas. Because it was necessary to resurvey the men before the end of basic training, no western centers could be visited in the time available. The men were not individually selected for this survey, entire training units of company size being processed at each installation. The sample consists of volunteers and of men inducted into the Army through Selective Service from the eastern half of the country during the spring of 1953. It is a series which has been medically screened for military service, with very short and tall men as well as the very light and heavy individuals eliminated. The age distribution of the series is relevant because of the well-known relationship of increasing fat with age. The mean age of the Whites was 20.7 years while that of the Negroes was 20.8. The variability of age was restricted (17 to 28 years old), as might be expected in a sample of military inductees.

The geographical restrictions of the sample will be apparent when regional area comparisons are presented later in this paper. Only 21 individuals are represented from the area west of the Great Plains. It is possible that the inclusion of a proportional sample from this area might alter the statistics on skinfold measurements and derived body fat, but it is doubtful that a radical revision would be required.

STATISTICAL VALUES FOR THE RACIAL SERIES

Ten measures have been used in the analyses. Seven of these (stature, weight, and 5 skinfolds) were taken on the men and three (relative weight, fat-free weight, and body fat) were calculated from the data. Stature was recorded as the maximum height to which the subject could stretch with the feet firmly on the ground and the head and eyes level. Weight was obtained on the nude subjects with a physician's type scale. The skinfold measurements have been described in a previous paper (Newman, '55). Relative weight, *i. e.*, actual body weight expressed as percentage of the so-called "standard" weight for height and age, was calculated from the data provided by the medico-actuarial mortality investigation of 1912 as given in Davenport ('23). The limitations of this standard in terms of body composition have been shown by Brožek and Keys ('50) and its doubtful applicability to a military population pointed out (Newman, '52). It has been included here because it remains a common standard even if an outmoded one. Body fat was calculated by the formula of Brožek and Keys ('51). Fat-free weight is body

TABLE 1

Presentation of White and Negro measures

2,017 Whites

	Mean	S. D.	PERCENTILE 5th	25th	50th	75th	95th
Stature (in)	68.9	2.5	65.0	67.2	68.9	70.6	73.2
Weight (lb)	154.0	22.7	122.6	138.1	151.4	166.3	195.5
Relative weight (percent)	105.2	13.7	87.6	96.5	103.5	112.6	131.4
Fat free weight (lb)	142.1	15.6	118.0	131.0	141.5	152.6	168.3
Body fat (percent of wt)	7.4	5.1	2.2	3.8	5.8	9.3	17.9
Chest skinfold (mm)	10.0	6.6	4.4	6.4	8.6	11.9	23.6
Arm skinfold (mm)	11.4	5.4	5.2	8.0	10.7	14.6	22.2
Back skinfold (mm)	13.6	6.0	8.2	10.3	12.1	16.1	25.9
Knee skinfold (mm)	15.0	5.8	8.5	11.2	14.4	18.5	26.4
Abdomen skinfold (mm)	14.6	7.9	6.9	9.5	12.6	18.5	31.8

361 Negroes

	Mean	S. D.	PERCENTILE 5th	25th	50th	75th	95th
Stature (in)	68.3	2.6	64.2	66.7	68.2	69.8	72.8
Weight (lb)	151.0	18.5	122.9	139.3	148.8	161.8	183.3
Relative weight (percent)	105.4	10.9	91.1	98.3	104.5	111.9	124.3
Fat free weight (lb)	144.5	14.9	121.1	133.9	143.4	154.4	169.4
Body fat (percent of wt)	4.6	3.4	1.1	2.7	3.7	5.5	10.0
Chest skinfold (mm)	6.5	3.7	4.1	4.9	5.9	7.8	12.0
Arm skinfold (mm)	8.2	4.0	4.4	6.1	7.8	10.0	15.8
Back skinfold (mm)	12.2	4.3	8.3	10.2	11.6	14.0	21.2
Knee skinfold (mm)	12.9	4.5	7.9	10.2	12.5	16.0	21.4
Abdomen skinfold (mm)	11.7	5.7	6.5	8.7	10.6	13.6	25.0

weight minus the calculated weight of the fat; it has been equated with the lean body mass (Behnke, '41).

The usual statistics on the racial samples are presented in table 1. Percentiles have been included along with the mean and standard deviation because those variables which include body fat are definitely skewed. A visual comparison of the means and medians (50th percentile) shows that only stature is truly symmetrical in distribution, with fat-free weight approaching symmetry.

RACIAL COMPARISON

It is apparent that the racial groups differ considerably in the amount of body fat. This has been graphically illustrated in figure 1 by plotting smoothed-curve distributions for body fat in terms of percentage frequency to equalize the numerical representation of the groups. The Negroes are not only more lean than the Whites, but their frequency distribution is remarkably narrow.

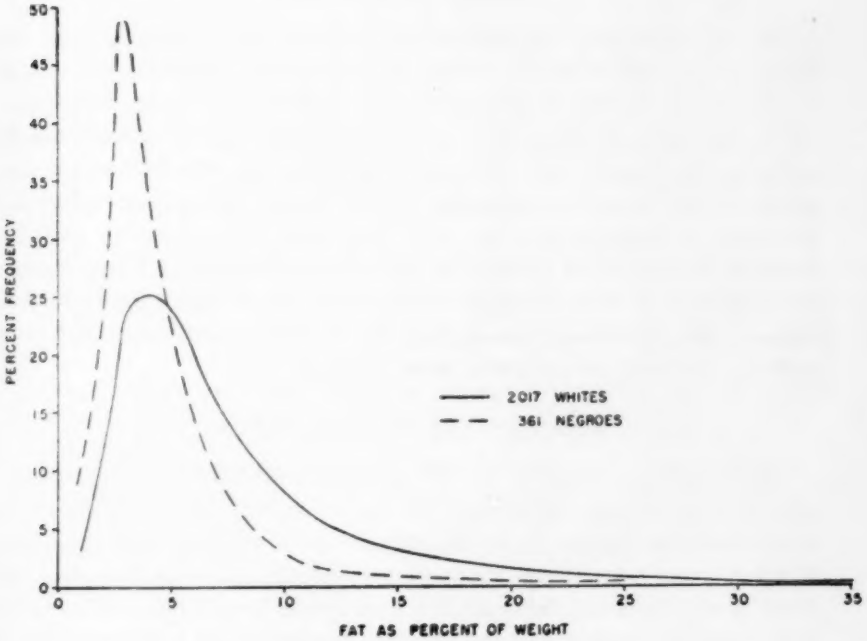

FIG. 1. DISTRIBUTION OF BODY FAT.

The statistical significance of the differences between the White and Negro mean values has been investigated by the use of Student's *t*-test. Unfortunately, this test presumes a "normal" distribution in both groups, a condition which is not fulfilled in most of these measures. Also, the large numbers of individuals involved result in statistical significance for minute differences which can have no biological meaning. All measures listed in table 1 show statistically significant differences at the 1% level except relative weight. Three of the measurements, body fat, chest skinfold, and arm skinfold, showed "*t*" values of much higher magnitude, indicating maximum differences in these variables. Since body fat is calculated from the measured thickness of chest and arm skinfolds (plus abdominal skinfold), it is these sites of subcutaneous fat which appear most distinctive between the racial groups. This phenomenon was noted in another type of analyses on this series and a possible explanation presented (Newman, '55).

REGIONAL COMPARISONS

In the following regional subsamples of these racial groups the analyses have been conditioned by the geographical distribution available in the series. It was necessary to select regional groupings which provided reasonable environmental and historical continuity without unduly reducing the sample size. Although no geographic selection which uses political boundaries can completely satisfy biological analyses, a regional grouping of states where the men were born was essential, and the Selective Service areas utilized in previous Quartermaster Corps anthropometric surveys were selected. These areas are shown in figure 2. Two regions, the Mountain States and the Pacific Coast, have not been included for lack of adequate representation.

NORTHERN AND SOUTHERN WHITES

A two-fold grouping of the White subjects into Northern and Southern is a convenient breakdown of the 7 regions shown in figure 2. Four northern regions (New England, Middle Atlantic. East and West North Central) and three southern regions (South Atlantic, East and West South Central) delineate the traditional boundaries. The means and standard deviations of the regional groupings are shown in table 2.

Within the same limitations mentioned in the Negro-White comparisons and with some doubt as to their applicability, a *t*-test of mean

FIG. 2. REGIONAL GROUPING OF NATAL STATES.

TABLE 2

Comparison of Northern and Southern Whites

	1,283 NORTHERN WHITES		713 SOUTHERN WHITES	
	Mean	S. D.	Mean	S. D.
Stature (in)	69.0	2.5	69.0	2.5
Weight (lb)	156.3	23.5	150.3	20.8
Relative weight (percent)	107.4	14.0	103.0	12.9
Fat free weight (lb)	143.4	15.8	139.9	15.0
Body fat (percent of wt)	7.9	5.3	6.4	4.6
Chest skinfold (mm)	10.6	6.9	9.0	5.7
Arm skinfold (mm)	12.0	5.6	10.4	5.0
Back skinfold (mm)	14.2	6.4	12.4	5.2
Knee skinfold (mm)	15.7	6.0	13.9	5.4
Abdomen skinfold (mm)	15.3	8.2	13.4	7.1

difference indicated statistically significant differences such as were found between Whites and Negroes. Except for height, the southerners have uniformly lower values, including both fat-free weight and those measures influenced by body fat. This indicates that the sizable weight difference (6 pounds) is not solely a matter of leanness-fatness; the southerns are lightly built with a demonstrably paucity of muscular tissue.

NORTHERN AND SOUTHERN NEGROES

An investigation of the Negroes on the basis of birthplace is complicated by two problems; one, over 80% of the Negroes were born in the south; and, two, there was an expectably large number of Negroes who were born in the south but who entered the Army at northern induction centers. For these reasons, the Negroes were separated into 4 groups on the basis of birthplace and induction center. Since it is apparent that body fat is the crucial element of geographical differences, only this variable has been used; the data are presented in table 3.

TABLE 3

Comparison of Northern and Southern Negroes in terms of body fat (as percentage of weight), estimated from skinfolds

	PERCENTAGE OF 361 Negroes	Number	BODY FAT Mean	S. D.
Born in the south; inducted in the south	66	239	4.2	2.6
Born in the south; inducted in the north	15	53	4.9	3.7
Born in the north; inducted in the north	18	64	5.4	4.0
Either birthplace; inducted in the north	33	117	5.2	3.9

It will be noticed that one possibility was omitted in this table: Negroes who were born in the north and were inducted in the south. Only 5 individuals fell into this category and this was much too small a sample for comparative purposes. It was not determined at what age the individuals born in the south but inducted in the north migrated or whether their residence was continuous. The *t*-test showed no statistically significant mean difference in body fat between the southern Negroes on the basis of place of induction, but those born and inducted in the north differed from those born and inducted in the south at the 5% level of significance. Negroes inducted in the north, regardless of

birthplace, differed significantly at the 5% level from those inducted in the south. This set of comparisons suggests either that a selective migration has occurred or that the northern environment (climatic, cultural, economic) leads to greater fat deposition. The findings on Negroes who were born in the south and inducted in the north, although not significantly different in body fat from those who remained in the south, strengthen the latter hypothesis.

REGIONAL COMPARISON IN WHITES

The large number of White soldiers available from the geographic regions shown in figure 2 can be listed by area and still maintain adequate samples. Only two regions, New England and West South Central, are sparsely represented. The means and standard deviations for the regional groups are given in table 4.

This table gives some idea of the proportional representation which went into the north-south comparison in table 2. There is a suspicion which would be difficult to verify because of the unequal numerical representation of the states that a band of relatively great obesity with medium muscularity stretches from New Jersey to Chicago and that this contrasts with a parallel band of leanness and low muscularity in what might be called the Deep South. New England and the Plains States appear peripheral to these concentrations of fatness and leanness but high in fat-free weight (muscularity). Hooton ('48) reached this conclusion in an analysis of body-build photographs of approximately 40,000 U. S. Army men. He found that the Middle Atlantic region had the highest concentration of fat men, and the highest percentage of what he termed muscular types occurred in New England. He ascribed the origin of the two diverse belts of body composition to the importance of national extraction. He says:

> Clearly the principal reasons why the Middle Atlantic and New England districts show such profusions of the well-muscled types and why the former district is so high in heavy men have to do with the population of recent foreign origin in these industrialized areas, which includes so many Southern, Eastern, and Central Europeans. These countries provide excesses of short, stocky, muscular men—even down to the second generation born in this country. On the other hand, districts such as Southern Atlantic and East South Central are mostly Old American (which implies mainly British and Irish derivation) and, consequently, the slender, tallish types of lighter musculature are likely to come in disproportionately large numbers from such regions.

TABLE 4

Regional values for White soldiers

	NEW ENGLAND		MIDDLE ATLANTIC		EAST NORTH CENTRAL		WEST NORTH CENTRAL		SOUTH ATLANTIC		EAST SOUTH CENTRAL		WEST SOUTH CENTRAL	
	Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.
Stature (in)	69.8	2.8	68.8	2.4	68.5	2.6	69.1	2.4	69.0	2.6	69.0	2.2	68.9	1.4
Weight (lb)	155.7	21.9	157.2	24.2	155.4	23.6	157.6	19.9	150.7	22.0	149.3	19.4	152.1	18.0
Relative weight (percent)	104.7	14.5	108.6	16.0	107.0	13.5	107.9	12.1	103.2	13.2	102.1	11.6	103.7	10.5
Fat free weight (lb)	144.9	15.5	143.7	16.0	142.6	16.3	144.8	14.0	140.4	15.6	139.0	13.9	140.8	15.0
Body fat (percent of wt)	7.0	4.1	8.0	5.9	8.0	5.3	7.6	5.0	6.4	4.6	6.4	4.5	7.0	4.6
Chest skinfold (mm)	10.0	5.4	11.2	7.5	11.4	7.1	10.8	6.2	9.3	5.7	9.5	5.5	10.1	6.0
Arm skinfold (mm)	11.5	4.5	12.8	6.2	12.5	5.4	12.4	5.4	10.8	5.0	10.8	5.0	11.6	4.6
Back skinfold (mm)	13.1	5.0	14.8	6.9	15.0	6.4	14.5	5.8	12.9	5.3	12.8	5.0	13.8	5.3
Knee skinfold (mm)	15.3	4.9	16.1	7.1	16.2	5.7	16.5	5.5	14.1	5.8	14.8	5.5	14.7	5.0
Abdomen skinfold (mm)	14.7	6.4	15.7	8.6	16.1	8.3	15.5	7.8	13.9	7.2	13.8	6.9	14.4	7.0
Number	87		328		637		231		407		254		52	

This hypothesis is difficult to reconcile with the data on Negroes shown in table 3 since there can be little question of subracial or national extraction influencing the north-south difference in body fat with this group. Several other causes are possible, such as climatic, economic, or nutritional background, and the relationships between these factors and a much larger U. S. Army series for which body weight was available have been discussed recently (Newman and Munro, '55).

SUMMARY AND CONCLUSIONS

Skinfold measurements and derived measures of body composition were obtained on a large series of young White adult males and a smaller series of young American Negro males. The limited age range and possible effects of military selection may restrict the applicability of the data for other purposes but not the internal reliability for comparisons. A racial contrast emphasized the leanness of the young Negro male and his distinctive deficiency of subcutaneous fat over the pectoral and triceps regions. Geographic grouping of the men indicated a regional difference between northerners and southerners in the amount of body fat for both Whites and Negroes. The causes of these differences in body fat are not fully clear but their relevance to human nutritional and ecological research is obvious.

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CORRELATIONS BETWEEN THICKNESS OF SKINFOLDS AND BODY DENSITY IN 88 SOLDIERS *

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INTRODUCTION

IT has been demonstrated that the thickness of skinfolds can be used as a quantitative criterion of leanness-fatness (Keys and Brožek, '53). Brožek and Keys ('51) have derived equations for prediction of body specific gravity from skinfold measurements. Experience in the use of these equations by this laboratory (Unpublished studies by L. R. Pascale and Medical Nutrition Laboratory, '53) indicated that the estimated body specific gravity was higher than would be expected in the groups of men studied. Refinements have been made in techniques for measurement of both skinfold thickness and body density since Brožek and Keys published their estimating equations. Calipers for measurement of skinfold thickness have been designed in which the jaw surfaces are always parallel and the spring tension is always constant regardless of the degree to which the calipers are open (Keys and Brožek, '53; Insull *et al.*, '54). One such caliper has been developed at this laboratory (Best, '53). In the measurement of body volume by underwater weighing, direct measurement of residual air volume of the lungs at the time the underwater weight is taken has been introduced and the calculations have been modified to give a more exact value of body density (Brožek *et al.*, '49; Keys and Brožek, '53).

In the present study skinfold thickness measurements were made at a number of different sites with calipers of two different designs, and the efficiency of these measurements, alone and in various combinations, in

* The opinions expressed in this paper are those of the authors and do not necessarily represent those of any governmental agency.

predicting body density as determined by underwater weighing was examined statistically.

METHODS

Subjects.

Healthy young soldiers at the post of Fitzsimons Army Hospital were used. A total of 100 men were studied, but the correlation analyses were carried out on only 88 of these, excluding non-Caucasians and men over 25 years of age. The means, ranges, and standard deviations of the ages, heights and weights of the 88 men used in the correlation analysis are presented in table 1. All subjects were fasting for at least 6 hours before the studies.

TABLE 1

Age, body weight and height of 88 subjects used in correlation analysis

	MEAN	STANDARD DEVIATION	RANGE
Age (years)	22.08	1.95	17 – 25
Body weight (kg)	68.28	11.13	49.7–109.8
Height (cm)	172.43	13.38	94 –193

Skinfold measurements.

Skinfold thickness measurements were made with both the Medical Nutrition Laboratory (MNL) and the Minnesota calipers 1953 model. The former has circular jaw faces measuring 25 mm^2 and the latter has rectangular jaw faces measuring 40 mm^2. Both calipers were calibrated so that the spring tension gave a pressure of 10 grams per square millimeter of jaw surface.

All skinfold measurements were made on the right side of the body. The skinfolds were grasped between the thumb and index finger. The span of the grasp was dependent on the thickness of the skinfold. The size of the skinfold held was great enough to include two thicknesses of skin and subcutaneous fat but not muscle or fascia. To insure against including such structures, when the measurer was in doubt he instructed the subject to perform an act which resulted in the contraction of the muscle underlying the skinfold held in the grasp. The calipers were applied about 1 cm from the fingers holding the skinfold and at a depth approximately equal to the thickness of the fold. All folds were taken in the vertical plane, except when the lines of Langer resulted in torsion

of the skinfold. Then the skinfold was taken along these lines. The measurements were made of the following sites:

a. *Chest:*
   1) at the level of the xyphoid in the mid-axillary line (MAL),
   2) midpoint between the anterior crease of the axilla and the nipple,
   3) just adjacent to the nipple along the line in 2), but not to include any glandular tissue.

b. *Abdomen:*
   1) waist level
      a) at the mid-axillary line,
      b) on the extension of the mid-clavicular line;
   2) umbilicus level
      a) at the mid-axillary line,
      b) at the mid-clavicular line,
      c) adjacent to the umbilicus.

c. *Arm:* taken at the midposterior midpoint between tip of the acromion and the tip of the olecranon, determined with the elbow in 90° flexion. The skinfold measurement was taken with the extremity hanging straight in an extended position.

d. *Back:* taken at the tip of the scapula with the subject in a relaxed standing position. Here the lines of Langer usually required the fold to be taken in the diagonal plane at about 45° from the horizontal and vertical planes medially upward and laterally downward.

Body Density Determination.

The densiometric measurements were made by the use of the Archimedean principle. Subjects measured during the forenoon were fasted from 9 p.m. the night before, and those weighed during the afternoon were fasted from 6:30 a.m. the day of the examination. Each day 4 men were weighed in the morning and 4 in the afternoon period. The subjects were weighed twice during the period with at least one and one-half hours between duplicate weighings.

The apparatus consisted of a canvas waterproof tank supported by a $2\frac{1}{2}$-inch aluminum pipe frame measuring $4 \times 4 \times 6$ feet. Suspended in this tank was an aluminum, legless seat set at the bottom of a frame measuring $2\frac{1}{2} \times 2\frac{1}{2} \times 4\frac{1}{2}$ feet. The seat hung from a Detecto scale which

had a capacity of 20 kilograms, with 20 gram scale divisions. The scale was suspended from a ¼ ton capacity electric hoist. The hoist was attached to a steel I-beam 13 feet above the floor level.

Attached to the frame of the seat was a respiratory "T" valve for controlling the source of inspired gas. One opening of the three was connected to a rubber mouthpiece, the second to a "snorkel" tube and the third to a source of approximately 99.7% oxygen and 0.3% inert gas (known exactly for each tank). The valve was arranged so that the mouth would be connected to only one of the gas sources at any time. A respiratory flutter valve was attached to the opening for oxygen supply. This allowed oxygen to enter from the delivery side of the valve during inspiration and restricted the backflow during expiration causing a forward flow of the expired air to a collecting Tissot spirometer.

Each subject immediately before being tested emptied his urinary bladder. He was then weighed to the nearest 10 grams in air on a Plima beam balance and was placed in the aluminum seat. The mouthpiece was put in his mouth and the airway connected to room air by means of the "snorkel" tube. The oxygen delivery and collecting system was flushed repeatedly with tank gas to insure that this gas was throughout the system. The nostrils were occluded completely with a nose clip. The water in the tank was kept between 32–36° C. The subjects were instructed to take in an average breath, the seat was lowered, and when the descent stopped they exhaled in a steady continuous forcible fashion to express all the air possible from their lungs. At the end of exhalation the tongue was inserted into the mouthpiece in order completely to occlude the opening. At this time the scale was released and the underwater weight was taken to the closest 20 grams. These weighings were repeated several times to get the maximal underwater weight and the minimal residual lung volume. With the subject adequately conditioned the final weight was taken as the weight for the calculation of the body density. At this time, with the mouthpiece still occluded, the respiratory valve was turned to the oxygen delivery line and the subject was then brought out of the water and allowed to breathe quietly for 7 minutes. All exhaled air was collected during this time and at the end of the collection period the valve was closed to the line and 3–5 liters of oxygen flushed through. The volume and temperature of the expired gas was taken after the gas had been mixed for 3 minutes. The gas was then stored in mercury filled gas sampling bulbs before analysis. At the end of each test the tare weight of the scale and water temperature were taken.

The nitrogen content of the expired gas was analyzed in the Van Slyke apparatus using the method of Van Slyke and Sendroy ('32).

The residual lung volume was calculated by the method of Cournand *et al.* ('41).

The body density was computed by the method of Keys and Brožek ('53).

Both the skinfold thickness measurements and the body density determinations were done in duplicate several hours apart.

Relative body weight was calculated from the values of the Medico-Actuarial tables as given by Davenport ('23).

TABLE 2

First order correlation coefficients between body density and skinfold thicknesses at various sites measured with two types of calipers

SITE	REGION	CALIPER USED FOR MEASUREMENT MNL	MINN. (1953 model)
	A. Chest		
a	1. mid-axillary line (MAL) at xyphoid	—.8281	—.8173
b	2. midpoint between anterior crease of axilla and nipple	—.7889	—.7992
c	3. juxta nipple	—.8251	—.8101
	B. Abdomen		
	1. waist level		
d	a. mid-axillary line	—.7383	—.6877
e	b. mid-clavicular line	—.7308	—.7077
	2. umbilicus level		
f	a. mid-axillary line	—.7129	—.6983
g	b. mid-clavicular line	—.7203	—.7030
h	c. adjacent to umbilicus	—.7703	—.7593
i	C. Arm	—.7713	—.7513
j	D. Back	—.7397	—.7046

RESULTS

The precision of the density measurements was estimated from the duplicate determinations by the method of Youden ('51) where S. D. $= \sqrt{\frac{\Sigma d^2}{2n}}$, where S. D. is the standard deviation of a single deter-

TABLE 3

Percentile distribution of relative body weight, density and skinfold thicknesses
($N = 88$)

CRITERION	PERCENTILES				MEDIAN		
	20	40	60	80	50	MEAN	S. D.
Relative body weight	90.04	95.37	101.33	108.17	97.82	100.71	13.37
Body density	1.0579	1.0657	1.0718	1.0771	1.0694	1.0678	.0120
Skinfolds (cm):							
Chest, MAL xyphoid	.59	.79	.96	1.21	.85	1.04	.60
Chest, juxta nipple	.78	1.02	1.23	1.60	1.15	1.36	.79
Abdomen, umbilicus level	.96	1.27	1.60	2.03	1.42	1.64	.88
Arm	.83	1.02	1.25	1.49	1.10	1.21	.46
Back	.88	1.04	1.18	1.47	1.08	1.22	.50

mination, d is the difference between duplicate determinations and n is the number of pairs of determinations. This gave a value of 0.0024 which is comparable to the values reported by Keys and Brožek ('53).

Table 2 presents the first order correlation coefficients between body density and skinfold thickness at various sites measured with the two different calipers. In all but one instance (site b) the correlation coefficient is higher for the measurements made with the MNL caliper than for those made with the Minnesota caliper. All further correlation analyses were performed only on the values for the MNL calipers. Those sites which showed the highest correlation coefficients for each area of the body were used for subsequent multiple regression analyses (sites a, e, h, i and j).

TABLE 4

Frequency distribution of body density values
($N = 88$)

BODY DENSITY CLASS INTERVAL	MEN	FREQUENCY %	CUMULATIVE %
1.020–1.029	1	1.1364	100.0000
1.030–1.039	3	3.4091	98.8636
1.040–1.049	3	3.4091	95.4545
1.050–1.059	12	13.6364	92.0454
1.060–1.069	28	31.8182	78.4090
1.070–1.079	28	31.8182	45.5908
1.080–1.089	13	14.7727	14.7727

The distribution of body density, skinfold thicknesses and relative body weight by percentiles is presented in table 3 together with the means and standard deviations for these values. Table 4 gives the frequency distribution of the body density values.

Table 5 presents the prediction equations for estimation of body density from individual skinfolds and relative body weight. In table 6 the forecasting efficiency (F. E.) and standard errors of estimate for these same criteria of leanness-fatness are given.

Multiple regression analysis was performed by the method of Doolittle (cited by Johnson, '49). The intercorrelations between the

various indices of leanness-fatness appear in table 7. Using these 6 variables the following multiple regression equation was obtained:

$$\hat{Y} = 1.080120 - .012031X_1 - .005775X_2 + .000004X_3 - .007113X_4 + .007549X_5 + .007416X_6 \quad \text{(I)}$$

TABLE 5

Equations for prediction of body density ($\hat{Y} = a + bX$) on the basis of single factor criteria. (Skinfold values are in cm)

VARIATE	
Skinfolds:	
Chest, MAL xyphoid	$1.0849 - .0164X_1$
Chest, juxta nipple	$1.0849 - .0126X_2$
Abdomen, umbilicus level	$1.0851 - .0105X_3$
Arm	$1.0923 - .0202X_4$
Back	$1.0896 - .0179X_5$
Relative body weight	$1.1251 - .0569X_6$

TABLE 6

Coefficients of correlation (r) between body density and other criteria of fatness-leanness, indices of forecasting efficiency (F. E.), and standard errors of estimate of the body density (S. E. E.)

VARIATE	r	F. E.	S. E. E.
Skinfolds:			
Chest, MAL xyphoid	—.8281	43.9	.0067
Chest, juxta nipple	—.8251	43.5	.0068
Abdomen, umbilicus level	—.7703	36.2	.0077
Arm	—.7713	36.4	.0076
Back	—.7397	32.7	.0081
Relative body weight	—.6342	22.7	.0093

$$\text{F. E.} = 100(1 - \sqrt{1 - r^2})$$

$$\text{S. E. E.} = SD_y\sqrt{1 - r^2}$$

The coefficient of multiple correlation between density and the 6 prediction variables was $R = 0.8609$. The standard error of estimate was 0.00636 and index of prediction efficiency was 49.1%. Those variables

that did not contribute significantly to the accuracy of predictions were deleted, giving the following equation:

$$\hat{Y} = 1.088468 - .007123X_1 - .004834X_2 - .005513X_4$$

for which $R = 0.8495$, standard error of estimate $= 0.00648$ and F. E. $= 47.3\%$.

TABLE 7

Intercorrelations between indices of fatness ($N = 88$)

Where Y = Body Density
X_1 = Chest, MAL xyphoid
X_2 = Chest, juxta nipple
X_3 = Abdomen, umbilicus level
X_4 = Arm
X_5 = Back
X_6 = Relative body weight

	X_6	X_5	X_4	X_3	X_2	X_1
Body Density (Y)	—.634149	—.739663	—.771324	—.770310	—.825134	—.828078
Skinfolds						
X_1	.806303	.923470	.828742	.902424	.927314	
X_2	.766231	.890953	.829112	.895559		
X_3	.802624	.837442	.778346			
X_4	.730315	.821973				
X_5	.835712					

Figure 1 is a scatter-diagram of the individual values for chest skinfold thickness (mid-axillary line at the level of the xyphoid) and body density.

DISCUSSION

It was hoped that the use of improved methods for the determination of body density and skinfold thicknesses would lead to more efficient prediction equations. This did not occur. Comparing our results with those of Brožek and Keys ('51) the following criteria of prediction efficiency are obtained (using the 3 variable equation in each instance):

	R	S. E. E.	F. E.
MNL	0.8496	0.00648	47.3%
Brožek and Keys	0.8709	0.00722	50.9%

It should be noted, however, that the skinfold sites represented by these

two analyses are not the same. Chest and arm skinfolds were used in both, but in the study of Brožek and Keys the third site was the abdomen whereas in the present study the relative efficiency of the various sites dictated the use of the fold at the level of the xyphoid in the mid-axillary line as the third site.

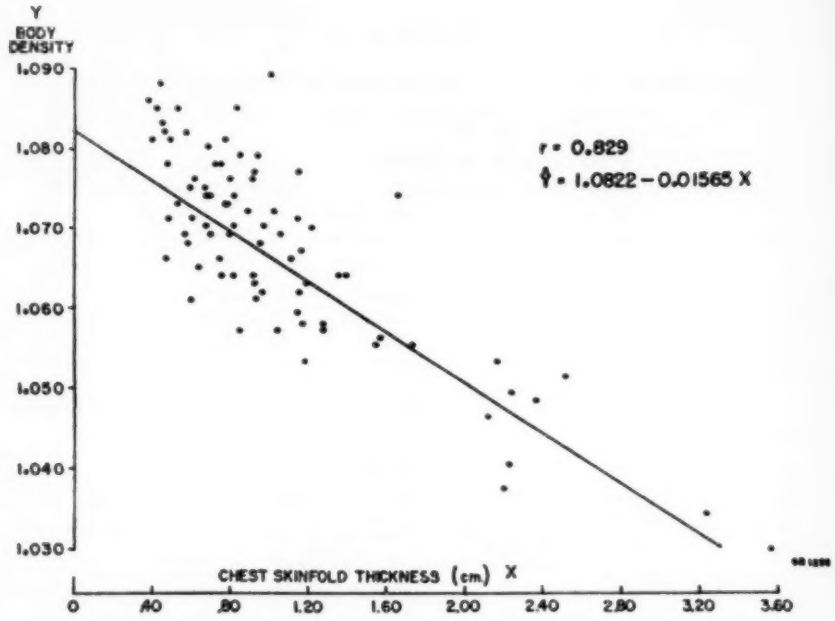

FIG. 1. RELATION BETWEEN BODY DENSITY AND THICKNESS OF CHEST SKINFOLD IN 88 YOUNG MEN.

Substituting the mean values of the present study for the indicated skinfold thicknesses of the equation of Brožek and Keys (their equation No. 3) we obtain an estimated mean specific gravity of 1.0764. Assuming that the measurements were made in water at 35 to 36° C ($d = 0.994$), this would correspond to a density of 1.0699 whereas the observed mean density was 1.0678. This confirms our impression that with the skinfold thickness values obtained from the calipers in current use (including the Minnesota 1953 design), the estimation of specific gravity by the Brožek-Keys equation gives for young soldiers values that are too high.*

* Editor's Note: The equation was derived for skinfold calipers with a pressure of about 35 gm/mm² (Minn. model 1948). A correction for pressure would have increased the difference.

One of the objects of this study was to determine which sites for skinfold thickness measurement on the chest and abdomen have the greatest power in predicting body density. Brožek *et al.* ('54) have shown that there is a considerable gradient of skinfold thickness as the site of measurement moves from the nipple or the umbilicus. Exact definition of the site of measurement therefore assumes importance both in terms of reproducibility of measurements and in terms of prediction efficiency. Using the first order correlation coefficients as indices of prediction efficiency it will be seen from table 2 that on the chest the site immediately adjacent to the nipple (site c) is superior to the site at the mid-point between the nipple and the anterior axillary fold (site b). In addition, the site in the mid-axillary line at the level of the xyphoid has the highest r value of any of the sites measured in this study and, since it is relatively far removed from the juxta-nipple site, it was retained as one of the sites used in the regression analyses. On the abdomen the site adjacent to the umbilicus proved to have the highest r value (site h, table 2).

SUMMARY AND CONCLUSIONS

In 88 healthy young soldiers (mean age 22.1 years), skinfold measurement were made at a variety of sites; body density was measured by underwater weighing. Using only those sites of skinfold thickness measurement which contributed significantly to the prediction efficiency, the following multiple regression equation was derived:

$$\hat{Y} = 1.088468 - .007123X_1 - .004834X_2 - .005513X_4$$

where Y is estimated body density, X_1, X_2 and X_4 are skinfold thicknesses in centimeters taken respectively at the chest in the mid-axillary line at the level of the xyphoid, at the chest in the juxta-nipple position, and on the dorsum of the arm at the midpoint between the tip of the acromion and the tip of the olecranon. The multiple regression coefficient, R, for this equation was 0.85 and the standard error of estimate was 0.0065 body density units.

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THE CANADIAN WEIGHT–HEIGHT SURVEY

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THE standard of living and way of life of Canadians is similar in many respect to that of citizens of the United States. Both population groups are endowed with an abundance of foodstuffs and are therefore exposed to the hazards of overnutrition. Before launching or endorsing a campaign against overweight in Canada, a critical study was made of the standards for weight and the criteria used to diagnose obesity. Many sets of tables were in use as "standards" but none had the valid mathematical basis that was desired. Confusion existed over the definition of "overweight" and "obesity" and no objective data were available on different body types.

Although no one seriously questions the evidence that many degenerative diseases are more prevalent among overweight people, it is not clear whether the villain is body weight itself or fat metabolism. The questions of total fat content of the diet and of various fat fractions in the blood were scrutinized. The possibility that people who have lost weight and then regained some or all of it back may develop more severe hypertension than if they had never reduced was a further deterrent to hasty propaganda.[1] The high percentage of relapses in weight control programs and the mental health aspects must also be considered.

It was an opportune moment in Canada to undertake an anthropometric study of the population, as recommended in the Second FAO/WHO Nutrition report of 1952. The results of the 1951 census had just become available and the Dominion Bureau of Statistics agreed to provide a sampling plan based on methods used for many years in sampling the Labour Force. The object was to obtain a representative

[1] *Cf.* J. Brožek, C. B. Chapman and A. Keys, 1948, Drastic food restriction: Effect on cardiovascular dynamics. J. Am. Med. Assoc., *137*: 1569-1574.

sample of the entire population on which height and weight measurement could be made. From these data, tables of average weight for height, age and sex could be constructed, which would indicate the situation as it actually existed and provide a base line from which further and more complete studies could be started.

METHOD AND EQUIPMENT

The sample was selected by an area stratification plan, proportionate to population density. The entire country was divided into primary sampling units, each of which had a dominant characteristic such as a particular industry, type of farming, soil type, climate, national extraction or others. All sampling units with similar basic characteristics were grouped together into a stratum and one or more units were selected by random procedure to represent all the units in the stratum. These units were not necessarily of equal size nor were they contiguous, but the randomization gave each Canadian an equal chance of being included in the sample.

This process yielded 59 units in which to make measurements, 13 of which were metropolitan. The non-metropolitan units were subdivided into urban, rural non-farm and rural farm areas for further random selection according to the number of persons to be measured. In the metropolitan areas a selection of city blocks was used. In each area approximately 0.1% of the population of the stratum was examined because this figure gave about 400 individuals in each sex and age group of the final table planned. It must be emphasized that the plan was drawn up according to resources available, *e.g.*, by grouping certain ages, in a manner that would not affect the random nature of the sampling. Large scale maps of each area were obtained and the specified number of households were selected from lists of census visitation records. Thus the sample was located geographically and, to a considerable extent, pinpointed on maps.

Since it was not possible to pre-determine the age of each person to be visited, it was decided that a suitable dispersion of ages would result from combining three different sources:

1. Schools where all children between 5 and 16 years could be located and visited according to the necessary ratio.

2. Business establishments employing 15 or more persons, an arbitrary category used because records of such establishments are available in lists from which random selection could be made.

3. Households where housewives, pre-school children, older persons, and others not covered above could be reached.

Excluded were those confined to bed through illness, pregnant women, children under two years, Armed Service personnel in camp or barracks, Indians on reserves, and certain classes of cripples and invalids. Allowances were made for non-interviews and these amounted to about 20% for all reasons. In a few areas, special efforts to sample this 20% yielded data that suggest no difference in averages from the main sample.

The task of weighing and measuring the persons selected in this widely scattered sample was undertaken only after careful preparations had been made. The selection of suitable equipment, the training of field workers and a standardized recording and reporting procedure were all important considerations.

The nature of the survey demanded that the equipment be readily portable and rugged enough to withstand severe handling. The biggest problem proved to be the selection of scales. Many types of scales were considered and those finally selected were a spring type with a circular dial and moving needle that could be read to the nearest ½ pound from any angle. This feature minimized the error due to parallax. The scales were checked at frequent intervals for accuracy, using standard weights. The measuring rod was of the collapsible telescopic type with a horizontal cross-bar. Height measurements were made to the nearest ¼ inch with the subject standing in a normal upright position, but without drawing up to his greatest height by pressing against a solid wall. The skinfold calipers were designed and manufactured in the Laboratory of Physiological Hygiene at the University of Minnesota. These calipers contained a constant tension device (10 grams per sq mm) and measured over a constant area of skin (40 sq mm). Readings were made to the nearest millimeter. Difficulties in obtaining the necessary instruments in time prevented the use of the metric system in recording weights and heights.

It was felt that a small number of thoroughly trained field workers would be preferable to a large number of part time workers. For this reason, the nutritionists and nurses on the regular staff of this Nutrition Division were assigned to the job of collecting the data. They were all experienced in interview technique and could readily adapt themselves to this new work.

To formulate a standardized procedure for obtaining the data, a pilot study was undertaken in an Ottawa suburb. The many difficulties

that arose were discussed and ironed out and it was at this point that we decided to limit the number of measurements taken to what seemed feasible with a minimum of refusals. For example, the site of the skinfold measurement was confined to the back of the upper arm and we dispensed with sitting height and other possible measurements because they were too difficult to obtain under the conditions of the present study. The precise sampling method demanded that the highest possible yield be obtained, and to achieve this, the cooperation of the public was essential. This fact was impressed on each field worker and they managed to keep the non-interview rate at a low figure.

The examiners worked alone or in pairs and travelled to all 59 sampling areas across the country. They usually obtained the help of a local person from a health unit or district census office to act as a driver and guide. The cooperation of the local Medical Officer of Health was obtained and an advance letter explaining the purpose of the survey and signed by the Medical Officer was sent to each participating household. This association with a familiar name and local letterhead had a reassuring effect on most householders and greatly simplified the work of the field worker in introducing herself.

Participants were weighed and measured and the skinfold measurement obtained while in usual indoor clothing *but with shoes removed.* The examiner then inquired the relationship to the head of the household and the month and year of birth. Our earlier investigation had revealed that people were more willing to state their year of birth than their age. The age in years was later calculated and recorded on the work sheets by the clerical staff, thus avoiding mental arithmetic on the spot.

The data sheets were returned daily to the central office for tabulating. As it was impossible to predetermine the ages of all persons falling in the sample, the cumulative totals for each age group were posted daily to detect any abnormalities in the dispersion of age groups. This method of control revealed that the sample provided a fairly good distribution of ages, with the exception of pre-school children, who for some unexplained reason, failed to appear in the expected numbers in the households visited. This group was subsequently dropped from the final table.

The field work began in March, 1953, and continued until October of that year. During that time, more than 22,000 Canadians were weighed and measured. The field workers visited many remote localities and used every conceivable means of transport to trace the randomly

selected persons on their lists. They succeeded in weighing and measuring over 80% of the original sample. This yield was considered by the statisticians to be adequate. Throughout the survey, consultations were held with sampling experts at the Dominion Bureau of Statistics. By eliminating bias in every possible way from the sample design, and by reducing personal and mechanical errors through special training and frequent inspection, stress was laid on the quality of the data. In this survey, quality was considered more important than sheer weight of numbers.

RESULTS

At the conclusion of the field work, the entire bulk of the raw data was turned over to the Dominion Bureau of Statistics for processing. A special punch card was designed, on which all details could be transcribed from the work sheets. The first step was to group the measurements into intervals of one inch and one pound. This was achieved by moving the $\frac{1}{4}$ inch figures down, the $\frac{3}{4}$ inch figures up and the $\frac{1}{2}$ inch alternately up and down as the cards were sorted. The $\frac{1}{2}$ pound figures were moved alternately up and down. A weighting factor was assigned to each person's measurements. This factor was calculated from the ratio of the sample to the total population in the sampling area.

The heights and weights reported are on individuals dressed in indoor clothing but with shoes removed. If weights are to be expressed as nude weights, a downward adjustment must be made on the figures in the table. The weight of men's clothing varied between 2 and 3 pounds, depending on the amount and type of textile in their attire. The uniformity of men's dress during the period of measurement (*i. e.*, shirt, trousers and underclothing) reduced the weight variation to a limit of one pound. With women, a wide variation in mode of dress was observed. In fact, it would be hazardous to speculate on the weight of impedimenta concealed on the more obese women. However, an average adjustment of 2 to 3 pounds could be made for women's indoor clothing. In children, the variation was greatest of all and varied from 1 to 3 pounds, depending on the size of the child.

The completed punch cards were run through a series of sortings on mechanical tabulating and calculating machines. These calculations resulted in a series of tables showing the weighted mean height, weight and skinfold for each age group and sex (table 1) and the average weight for each inch of height, age and sex (table 2) and percentile distributions (tables 3 to 5).

TABLE 1

Canadian average height, weight (in ordinary indoor clothing, without shoes), and skinfold by age and sex (1953 data)

AGE GROUP YEARS	SEX	AVERAGE HEIGHT (in)	AVERAGE HEIGHT (cm)	AVERAGE WEIGHT (lb)	AVERAGE WEIGHT (kg)	AVERAGE SKINFOLD (mm)
2	M	34.7	88.1	30	13.6	9.4
	F	33.6	85.3	28	12.7	9.5
3	M	36.6	93.0	32	14.5	9.0
	F	36.0	91.4	31	14.1	9.6
4	M	39.2	99.6	37	16.8	8.3
	F	39.2	99.6	36	16.3	9.3
5	M	41.9	106.4	40	18.1	7.5
	F	41.8	106.2	41	18.6	8.8
6	M	44.6	113.3	46	20.9	7.4
	F	44.2	112.3	44	20.0	8.8
7	M	47.0	119.4	50	22.7	6.9
	F	46.5	118.1	49	22.2	8.5
8	M	49.1	124.7	57	25.9	6.8
	F	48.9	124.2	57	25.9	8.9
9	M	51.3	130.3	63	28.6	7.1
	F	51.0	129.5	62	28.1	9.4
10	M	53.5	135.9	70	31.8	7.4
	F	53.3	135.4	69	31.3	9.5
11	M	55.4	140.7	77	34.9	7.9
	F	55.3	140.5	77	34.9	10.0
12	M	57.4	145.8	84	38.1	8.0
	F	58.2	147.8	92	41.7	10.5
13	M	59.3	150.6	94	42.6	8.3
	F	60.4	153.4	102	46.3	11.2
14	M	62.2	158.0	108	49.0	7.5
	F	61.3	155.7	107	48.5	11.3
15	M	64.7	164.3	119	54.0	6.5
	F	62.2	158.0	112	50.8	11.3
16–17	M	66.7	169.4	136	61.7	6.4
	F	62.5	158.8	120	54.4	13.3
18–19	M	68.0	172.7	144	65.3	6.0
	F	62.6	159.0	124	56.2	13.6
20–24	M	67.9	172.5	154	69.9	6.3
	F	62.8	159.5	124	56.2	12.4
25–29	M	68.3	173.5	160	72.6	7.0
	F	62.7	159.3	126	57.2	13.0
30–34	M	68.0	172.7	167	75.7	8.2
	F	62.8	159.5	130	59.0	14.3
35–44	M	67.5	171.4	167	75.7	7.7
	F	62.4	158.5	135	61.2	15.5
45–54	M	66.9	169.9	164	74.4	7.5
	F	61.8	157.0	144	65.3	17.7
55–64	M	66.0	167.6	161	73.0	6.9
	F	61.3	155.7	147	66.7	17.7
65 and over	M	65.4	166.4	155	70.3	5.6
	F	60.6	153.9	138	62.6	15.5

TABLE 2

Canadian average weights for height and age (in ordinary indoor clothing, without shoes)

For young adults, the average (mean) weight at a given height is probably the weight desirable for health. After the age of 30 years most people should maintain their weight below the figure in the table. Variation in body types may account for differences up to 10% above or below the weight at a given height.

MEN

HEIGHT IN FEET-INCHES	AGE IN YEARS 15	16–17	18–19	20–24	25–29	30–34	35–44	45–54	55–64	65 AND OVER
4′ 9″	83									
10	88									
11	92	99	116	121	128	134	135	127	138	126
5 0	97	103	119	124	132	138	139	132	141	130
1	102	108	122	127	135	141	142	136	144	135
2	106	113	125	131	139	145	146	141	148	140
3	111	118	128	134	142	148	150	146	151	144
4	116	122	131	138	146	152	153	150	154	149
5	121	127	134	142	149	156	157	155	157	154
6	125	132	138	145	153	159	161	160	160	158
7	130	136	141	149	156	163	164	165	163	163
8	135	141	144	152	160	166	168	169	166	167
9	139	146	147	156	163	170	172	174	169	172
10	144	151	150	159	167	173	175	179	172	177
11	148	155	153	163	170	177	179	183	176	181
6 0	153	160	156	166	174	181	183	188	179	186
1	158	165	160	170	177	184	186	193	182	191
2	163	169	163	173	181	188	190	197	185	195
3	167	174	166	177	184	191	194	202	188	200

WOMEN

HEIGHT IN FEET-INCHES	AGE IN YEARS 15	16–17	18–19	20–24	25–29	30–34	35–44	45–54	55–64	65 AND OVER
4′ 8″	96	105	100	106	110	115	126	130	134	120
9	99	107	103	108	112	117	127	132	137	124
10	101	110	107	111	114	119	128	134	139	128
11	104	112	110	113	117	122	130	137	141	132
5 0	107	115	114	116	119	124	131	139	144	136
1	109	117	118	118	122	126	133	142	146	140
2	112	120	121	121	124	129	134	144	148	144
3	115	122	125	123	127	131	135	146	151	148
4	117	125	129	126	129	133	137	149	153	152
5	120	127	132	128	132	136	138	151	155	157
6	123	130	136	131	134	138	140	153	158	161
7	126	132	140	133	137	140	141	156	160	165
8	128	135	143	136	139	143	143	158	162	169
9	131	137	147	138	141	145	144	160	165	173
10	134	140	151	141	144	147	145	163	167	177
11	136	142	154	143	146	150	147	165	169	181

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TABLE 3

Canadian height and weight survey
Percentiles of height (in centimeters) by age and sex

AGE GROUP YEARS	SEX	P_{25}	P_{50}	P_{75}
2	M+F	83.1	86.6	89.9
3	M+F	88.6	91.7	95.2
4	M+F	96.5	99.6	103.4
5	M+F	103.1	106.9	110.5
6	M+F	109.2	113.3	116.3
7	M	114.8	118.9	122.9
	F	114.3	118.4	121.9
8	M	120.9	124.5	128.3
	F	119.2	124.2	128.3
9	M	126.2	130.3	134.9
	F	125.5	129.0	133.9
10	M	130.8	135.4	140.5
	F	130.3	134.9	139.7
11	M	135.4	140.5	145.8
	F	134.6	140.5	145.5
12	M	140.2	145.3	150.9
	F	142.0	148.1	153.2
13	M	144.5	150.1	156.7
	F	149.1	153.7	158.2
14	M	151.1	158.0	165.1
	F	149.9	155.7	160.5
15	M	158.0	165.1	171.2
	F	153.4	158.0	162.6
16–17	M	167.9	171.7	176.8
	F	154.4	159.0	163.1
18–19	M	168.4	173.2	176.8
	F	155.2	159.3	162.8
20–24	M	168.1	173.5	177.3
	F	155.2	159.8	163.6
25–29	M	167.9	173.5	179.6
	F	154.7	159.0	163.1
30–34	M	168.1	173.0	178.1
	F	155.2	159.0	163.3
35–44	M	166.9	171.7	177.3
	F	154.2	158.5	162.6
45–54	M	164.6	169.7	175.3
	F	152.9	157.0	160.5
55–64	M	162.1	167.6	173.2
	F	151.6	154.9	159.5
65 and over	M	161.0	165.4	170.7
	F	149.6	153.9	158.2

TABLE 4

Canadian height and weight survey
Percentiles of weight (in kilograms) by age and sex

AGE GROUP YEARS	SEX	P_{25}	P_{50}	P_{75}
2	M+F	12.1	13.2	14.2
3	M+F	13.0	14.2	15.5
4	M+F	15.2	16.5	17.6
5	M+F	16.7	17.8	19.9
6	M+F	18.5	20.2	22.0
7	M	20.6	22.6	24.6
	F	19.7	21.9	24.4
8	M	23.0	25.4	27.7
	F	22.1	24.5	27.8
9	M	25.7	28.2	30.9
	F	23.8	27.2	31.2
10	M	27.8	30.8	34.5
	F	27.3	30.3	34.2
11	M	30.6	33.9	38.0
	F	29.6	33.3	39.0
12	M	33.3	37.0	42.0
	F	34.8	40.5	46.6
13	M	36.6	41.3	46.8
	F	40.7	46.4	50.5
14	M	41.9	47.9	54.3
	F	42.3	47.4	53.7
15	M	45.9	53.9	60.9
	F	45.2	50.0	55.8
16–17	M	56.2	61.4	67.4
	F	48.9	54.6	59.3
18–19	M	59.1	63.7	71.1
	F	50.7	54.6	59.2
20–24	M	63.6	68.3	73.9
	F	50.2	55.2	60.9
25–29	M	65.5	71.3	79.9
	F	50.5	56.0	61.8
30–34	M	67.5	76.1	82.0
	F	51.6	57.0	64.9
35–44	M	67.6	74.9	82.8
	F	54.5	59.9	66.3
45–54	M	65.5	73.0	82.1
	F	56.4	64.3	72.8
55–64	M	64.8	72.1	79.4
	F	58.2	65.8	75.2
65 and over	M	61.1	70.6	78.2
	F	54.4	61.5	69.3

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TABLE 5

Canadian height and weight survey
Percentiles of skinfold (in millimeters) by age and sex

AGE GROUP YEARS	SEX	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}
2	M+F		7.8	9.4	10.7	
3	M+F		7.6	9.1	11.0	
4	M+F		7.2	8.5	10.2	
5	M+F		6.3	7.7	9.6	
6	M+F		6.1	7.6	9.4	
7	M	4.2	5.1	6.4	8.1	9.8
	F	5.5	6.6	8.0	9.7	12.1
8	M	4.2	5.1	6.4	8.1	9.6
	F	5.5	6.6	8.5	10.5	12.9
9	M	4.3	5.1	6.4	8.1	10.4
	F	5.6	6.9	8.5	11.0	14.6
10	M	4.4	5.2	6.7	8.4	11.3
	F	5.3	6.8	8.6	11.0	14.6
11	M	4.2	5.4	7.0	9.2	12.3
	F	5.4	7.0	9.1	12.0	15.4
12	M	4.2	5.2	6.9	9.7	12.5
	F	5.7	7.1	8.9	12.4	18.1
13	M	4.1	5.3	6.7	9.5	13.9
	F	5.9	7.5	10.0	13.8	17.3
14	M	3.7	4.6	6.2	8.4	13.0
	F	5.8	7.8	10.7	13.4	17.4
15	M	3.4	4.4	5.4	7.8	10.5
	F	6.2	7.9	10.2	14.3	17.5
16–17	M	3.2	4.0	5.2	7.8	10.9
	F	7.0	9.5	13.1	16.4	20.2
18–19	M	3.1	4.0	5.3	6.9	9.5
	F	6.8	9.6	13.1	17.3	20.1
20–24	M	3.2	4.0	5.3	7.5	10.4
	F	5.9	8.0	11.2	15.3	19.8
25–29	M	3.3	4.4	5.8	8.8	11.5
	F	6.1	8.3	11.7	16.3	21.5
30–34	M	3.4	4.7	7.3	10.1	14.4
	F	6.6	8.4	12.7	18.1	24.9
35–44	M	3.4	4.8	7.0	9.8	13.1
	F	7.7	10.2	14.4	20.2	24.8
45–54	M	3.1	4.2	6.6	9.9	13.7
	F	9.1	11.8	17.5	22.4	26.8
55–64	M	2.9	4.0	5.6	8.2	12.9
	F	9.9	12.9	17.0	21.7	28.0
65 and over	M	2.6	3.3	4.4	6.5	10.5
	F	6.5	10.1	14.3	20.2	25.0

To extend the height-weight figures to the extremes of height where real data were lacking or limited, it became necessary to establish curves for height and weight in each age group, using the methods of least squares and three moving averages. No attempt was made in table 2 to smooth the differences in weight at any given height in the various age groups.[2] Reading the table vertically, there is naturally a weight increment with increasing height, but horizontally there are variations up and down with increasing age which may have a physiological basis—for example, the decrease in average weights for men over 65 years of age may be the result of increased mortality in those who are overweight, especially at shorter heights. These are problems which require further investigation, and which we intend to pursue.

What is a proper interpretation of these figures? Are they "ideal" or "desirable"? The first answer is that the new Canadian averages provide a standard or reference point that is much clearer in its derivation and significance for the population than any previous figures.

No figure for weight can ever be used as an absolute standard. Some variation is permitted. One widely used insurance table lists weights for three types of body "frame" at each height, but without defining "frame"; it then lists two figures under each type without advice on when to use the lower, and when the higher figure. This presentation has been useful to allow some latitude in each category, but to use it properly would require definitions and judgment. Similar approach has been used in referring to tables giving a single weight, presumably "ideal"; it is customary to allow 5, 10 or even 20% of the figure given, above or below, according to the purpose in mind.

Such adjustments can be applied to the new table of Canadian average weights, with the added advantage that the starting point has a clear relationship to the population, and is therefore much better than figures derived in unknown ways or from limited groups. Thus if the specialist considers that diabetic patients should maintain weight 10% below the average, it is just as easy for him to refer to the Canadian weight standard as to use any other yardstick. He has the additional information that more than half the people in the particular age-sex-height group weigh more than the weight he has selected (10% below the figure in this table). Conversely, if a person asks a physician

[2] Editor's Note: For actual use *smoothed* values would be preferable. This would eliminate "accidental," unsystematic ups and downs, without affecting the age trends.

whether she must gain weight up to the figure in the table of averages, he has an excellent opportunity to explain that an average is a kind of mid-point, with many people normally below and above.

Is a person overweight if he or she is above average? They may be. There is increasing evidence that "overweight" by itself, as judged in older tables by the use of 10 or 20% limits, is not as significant in the big killers like cardiovascular-renal disease as combining a consideration of weight with a measurement of subcutaneous tissue (the skinfold measurement). The combined measurements will provide a research tool for much better evaluation of patients than arbitrary percentages of "average weights" taken from tables of uncertain origin or validity.

ANTHROPOMETRY AND NUTRITIONAL STATUS OF ADULT WOMEN [1]

BY MARGARET A. OHLSON,[2] ALICE BIESTER,[2] W. D. BREWER,[2] BETTY E. HAWTHORNE [2] AND MARIE BOHLAND HUTCHINSON [3]

FEW studies of the anthropometry of living adult women have appeared in the literature and none of these include significant numbers of subjects in the upper age brackets.

The measurements presented in this paper were made as a part of an extended investigation into the nutritional status of women. The study was initiated in 1935 as a regional project of the agricultural experiment stations of the North Central states. Five of the groups cooperated in the measurement of 1013 freshman college women aged 17 to 21 years (Donelson *et al.*, '40). This study provides a point of reference for evaluating the present series since the subjects were from the same geographical areas and common techniques were used. In 1947, a second regional project was organized to collect similar data on the nutritional status of adult women living in their own homes. Particular effort was made to include women more than 50 years of age. Anthropometric measurements made at the Michigan and Minnesota stations form the basis of this report.

[1] Contribution No. 12, Subproject 1, "The Nutritional Status and Dietary Needs of Older People" of the North Central Region Cooperative Project NC-5 "Nutritional Status and Dietary Needs of Population Groups."

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SUBJECTS

The subjects measured represent a limited sample, and the women from the two states may not be compared directly. Women measured in Minnesota came from Census Tract 1 in St. Paul, which is adjacent to the St. Paul campus of the University of Minnesota, with the exception of those above 80 who lived in the larger metropolitan area in which St. Paul and Minneapolis are located. The heads of three fifths of the households were professional or semi-professional workers; about one sixth were retired. The plan used in selecting the sample was devised with the help of the Department of Agricultural Economics. All women were of sufficient health and vigor to be brought to the laboratory for an extensive series of tests as well as the anthropometric measurements.

In Michigan, an area sample of women living within the metropolitan limits of Lansing and East Lansing was chosen. One hundred and four white women were interviewed in their homes and 40 of them were persuaded to come to the college laboratories for measurements and other physical and physiological tests. Because health and mobility determined, to a degree, the capacity of the women to participate, a large proportion of the physically infirm included in the original interviews were eliminated. However, selection did not change the character of the sample with respect to the distribution of women within the various economic and sociological groups. The area included is that of an industrial city and a wealthy industrial suburb.

The Michigan sample of Negro women represents an attempt to obtain an area sample of a limited housing district in an industrial city. The 102 women interviewed were of higher social status than is believed characteristic of the Negro community as a whole since the women of lesser social poise either refused to be interviewed or gave such unsatisfactory information that the interviews were discarded. Fifty of the Negro subjects came to the college to be measured.

The third series of Michigan women represents selected subjects studied as a part of a project on weight reduction.

EXPERIMENTAL METHODS

The techniques of measurement used are those described by Hrdlička in 1920 except as will be noted. Measurements chosen (stature, weight, transverse and antero-posterior diameter of chest, bi-iliac and bi-trochanter width, girth of the upper arm at the point just below the

insertion of the deltoid muscle and maximum calf girth) were thought to reflect nutrition and to be influenced to only a minor degree by temporary changes in hydration.[4]

Stature was measured on a platform with a rigid vertical upright to which a measuring tape was attached. The upright was 72 inches high and of the same width as the platform thus forming a solid support for the back. The subject was required to stand with the feet parallel, heels, buttocks and shoulders touching the upright and head held comfortably erect. A hardwood square in contact with the upright was brought down to touch the subject's head. Preliminary testing demonstrated that height could be measured by different investigators and at different times of the day with minimum variation with this technique as compared with the variations obtained without the back support.

Weight was determined with clothing weighing less than a pound and was not corrected for the weight of clothing. A Fairbanks balance was used and weight recorded to 0.01 kg. Measurements of width and girth were made with a standard metal caliper[5] and a steel tape calibrated in tenths of a centimeter.

RESULTS

The measurements, with standard deviations, of Michigan and Minnesota White women are given in table 1. College subjects from the earlier study from Ohio and Minnesota are included as Michigan college women were not studied in the earlier work. Michigan women for each age group are shorter, heavier, and larger than Minnesota women in each of the width and girth measurements recorded. Because numbers were limited, no calculations of significance of these differences have been made, though it is of some interest that, in the college series, Ohio women were significantly shorter than women from the other states, all of which were west of the Mississippi River.

There are a number of known variables in the sample which might influence stature. All of the women whose measurements are recorded in this table were born before the regular use of vitamin D during child-

[4] Editor's Note: The "bony" measurements, such as the bi-iliac diameter, may be measured with or without a pressure on the calipers adequate to minimize the effect of overlying soft tissues, depending on the investigator's purpose. Moderate pressure was used in this study.

[5] Made in France on specifications supplied by the personnel of the Smithsonian Institution.

TABLE 1

Means and standard deviations of body measurements of adult White women

MEASUREMENT	AGES											
	17–21		30–39	40–49		50–59		60–69		70–79		80–89
	OHIO	MINN.	MINN.	MICH.	MINN.	MICH.	MINN.	MICH.	MINN.	MICH.	MINN.	MINN.
No. of Subjects	160	187	20	12	20	9	20	12	20	10	20	20
Stature, cm	161.4	164.2	165.7	161.1	165.3	158.4	160.6	158.6	162.8	155.1	158.8	155.5
	±5.9	±5.7	±4.8	±5.2	±5.6	±4.9	±4.3	±5.1	±4.6	±8.1	±5.3	±6.6
Weight, kg	55.8	57.5	57.8	67.5	62.2	72.5	68.4	72.4	66.2	60.7	57.9	56.7
	±8.1	±7.2	±6.0	±15.4	±11.1	±12.1	±10.9	±7.2	±7.7	±9.5	±9.5	±8.3
Chest,	25.2	25.9	25.5	25.6	25.0	27.6	26.2	26.8	25.8	25.5	24.5	24.5
Lateral, cm	±1.6	±1.5	±1.6	±2.1	±1.5	±2.4	±2.2	±1.4	±1.9	±2.6	±1.9	±1.8
Chest, Antero-	18.3	18.4	17.5	19.7	18.5	20.5	19.5	21.1	20.4	21.0	20.2	20.0
posterior, cm	±1.5	±1.3	±0.9	±2.0	±1.4	±1.8	±1.5	±1.7	±2.4	±2.3	±1.4	±1.8
Arm Girth,	26.3	26.7	26.8	30.6	28.8	32.1	30.9	32.2	30.3	30.1	27.7	27.3
Right, cm	±2.6	±2.4	±2.1	±4.7	±3.4	±3.1	±2.9	±2.4	±2.5	±4.0	±3.0	±2.7
Bi-iliac, cm	—	—	28.6	29.8	28.6	30.8	30.1	31.1	31.1	31.1	30.6	30.9
	—	—	±1.3	±2.5	±1.8	±2.1	±1.5	±1.9	±1.4	±1.3	±1.6	±1.7
Calf Girth	35.0 *	35.7 *	34.6	35.9	35.2	37.0	36.3	37.0	35.0	33.7	32.0	32.9
Right, cm	±2.4	±2.3	±2.2	±3.8	±3.3	±4.1	±3.8	±3.2	±3.2	±1.5	±3.4	±2.9

* Ohio and Minn., calf girth, left.

hood and it is known that the levels of effective sunshine in Ohio and Michigan are lower than in the Western states. Iodine deficiency is a common finding in Michigan and affected about 50% of adolescent girls previous to the iodization of table salt in 1924. Since that time, the use of iodized salt is known to have varied widely.

The adult samples do not measure comparable population segments from the point of view of social stratification although a brief inspection of data available on family income would suggest that the buying power of the two groups was not too different.

Ethnic differences are more difficult to evaluate. Forty per cent of women from Minnesota and 50% from Michigan were native to their respective states. Twenty-seven per cent of Minnesota women were of Scandinavian inheritance and 42% represented the third generation of their families born on American soil. The remaining women were descended from Northern European stock except for 13%, for whom exact data for classification were missing. The Michigan sample also was derived largely from Northern European stock but inheritance was so mixed that further classification seemed unproductive. No one ethnic group dominated the Michigan sample.

Women in the fifth decade appeared to be shorter in both series than the younger subjects and women over 70 years were, on the average, three to four centimeters shorter than in the preceding decade. Numerous studies of college women and the compilation of heights and weights of working women published by Bayer and Gray ('34) would suggest that the stature of women had increased during the past 100 years. The apparent loss of height with age of women between 40 and 50 years, in this series, could be interpreted as reflecting the shorter stature of an earlier period. The lesser height of women over 50 years of age may reflect both an earlier birth date and an actual loss of stature with age.

Twelve women of the Michigan series, ranging in age from 48 to 77 years have been studied repeatedly during the past 10 years. Two of the women one 56 and the other 77 years old showed no change in stature, data on height was lacking for one subject in the seventies, and the other 9 subjects appeared to have lost from 0.5 to 2.0 centimeters in height. Losses of stature increased with the period of observation. There were both losses and gains of weight in individual women. Elderton *et al.* ('28) and Reynolds and Asakawa ('50) reported a similar trend for stature of women to decrease with age.

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One study published in 1931 of 26 women born in Holland, Michigan, of Dutch stock was found in the literature (Steggerda). The women were characterized as "middle aged" and were slightly taller and deeper chested than the present sample. The most significant difference in the comparable measurements was in the girth of the upper arm which was 4 to 5 cm smaller in the woman of Dutch ancestry.

The measurements of Negro women are given in table 2. The differences in measurements of Negro and White subjects from Michigan were slight and, for the most part, inconsistent. In general, the trans-

TABLE 2

Body measurements of adult Negro women

MEASUREMENT	AGES, YEARS 50–59	60–69
No. of Subjects	23	21
Stature, cm	161.0 ± 7.5	155.4 ± 7.7
Weight, kg	73.8 ± 15.7	69.9 ± 13.1
Chest, Lateral, cm	28.1 ± 2.9	27.6 ± 2.2
Chest, Antero-Posterior, cm	20.3 ± 1.9	20.5 ± 1.9
Arm Girth, Rt., cm	31.7 ± 4.0	32.4 ± 3.7
Bi-iliac, cm	29.9 ± 3.1	30.0 ± 2.2
Bi-trochanteric, cm	32.2 ± 3.1	32.2 ± 2.3
Calf Girth, Rt., cm	35.7 ± 3.7	36.2 ± 3.3

verse chest, bi-iliac and bi-trochanter widths and calf girth measurements were smaller in the Negro women. More of the Negro women reported employment requiring physical work than White women. Tasks such as ironing, cleaning walls and floors were done regularly and the differences in measurement are in keeping with the clinical impression that the Negro women of the series were more muscular and less fat than White women of the same height and weight. Wolff and Steggerda ('43) reported similar measurements of 100 Negro women of college age living in the South. The older women, most of whom had migrated from the South as adults, were shorter, heavier and larger in each of the width and girth measurements than the college series. Both groups of subjects were of the mixed blood characteristic of the American Negro. The number of subjects in the 7th and 8th decade was too small to study changes in stature with age in the Negro women of this series. Michelson ('43) found no difference in height of young adult Negro women measured in 1923 and 1941.

Maximum grip of the right and left hands[6] of this series of subjects is reported in table 3. The grip of the Negro subjects is higher for both hands at each age group, which again confirms the impression of better muscular development than that found in the White women.

Anthropometric measurements were made on this series of women to increase the usefulness of the total data in interpreting nutritional status. The measurements alone are merely descriptive of a population. A few low values of hemoglobin and vitamin C were found in studies of the blood chemistry (Chaloupka, Leverton and Diedricksen, '51, Roderuck *et al.*, '55, and Swanson, Leverton, Gram, Roberts and Pesik, '52) but clinical examinations did not reveal symptoms related to deficiency of nutrients. The food eaten was such that nutrient intakes correlated closely with intakes of calories and protein (Ohlson *et al.*, '52). The lower caloric intakes tended to be generally poor in all nutrients rather than specifically deficient in one. In spite of a large number of cases consuming fewer than 1800 calories per day, weight in excess of standards was frequent in the Michigan sample even when an allowance was made for greater size of chest and hips. Serious underweight was not found. Therefore the relation of excess weight to the measurements chosen was studied in a separate series of cases selected as a part of another project on weight control.

Table 4 presents the data on women of widely varying weight but chosen so that each group of three subjects was matched for age, height and other physiological characteristics. Each measurement increases with increased weight and the increases are larger between frankly obese subjects and those of normal weight for height than between the women of normal weight and those underweight. Skinfold measurements of the abdomen, back, upper arm and thigh just above the knee made with a skinfold caliper using the directions as outlined by the Laboratory of Physiological Hygiene of the University of Minnesota were plotted against percent deviation of weight in figure 1. Apparently the measurements given in table 4 do measure differences in fatness as well as possible differences in body build of the three groups of subject.

The relations between weight and the measurements chosen were explored further in figure 2 which records the change in each measurement which occurred in a group of obese subjects with increasing amount of weight lost. Each subject was reduced in weight with a diet

[6] Measured with a Narragansett dynamometer.

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TABLE 3

Hand grip in kg of adult White and Negro women

AGE IN YEARS	MICHIGAN NEGRO			MICHIGAN WHITE			MINNESOTA WHITE		
	No.	Right Hand	Left Hand	No.	Right Hand	Left Hand	No.	Right Hand	Left Hand
30–39							20	30.6 ± 4.1	26.3 ± 3.3
40–49				12	30.1 ± 5.2	27.7 ± 6.0	20	28.2 ± 3.2	25.0 ± 3.6
50–59	23	32.3 ± 7.6	31.1 ± 6.3	9	28.4 ± 6.1	27.2 ± 6.7	20	27.0 ± 2.7	24.4 ± 4.0
60–69	21	28.8 ± 8.3	28.2 ± 7.1	12	23.8 ± 4.6	22.7 ± 5.2	20	24.7 ± 3.6	22.6 ± 4.0
70–79	3	23.3 ± 2.9	21.7 ± 2.9	10	20.7 ± 3.5	22.1 ± 5.5	20	20.5 ± 4.3	17.4 ± 3.4
80–89	3	21.0 ± 3.6	20.0 ± 5.0	1	17	15	20	16.6 ± 3.2	15.3 ± 3.6

TABLE 4

Body measurements of selected groups of underweight, average-weight and overweight women

GROUP	NO.	RANGE OF AGE	HEIGHT	RANGE OF WEIGHT	CHEST, LATERAL	CHEST, ANTERO-POSTERIOR	ARM GIRTH, RT.	BI-ILIAC	BI-TRO-CHANTERIC	CALF GIRTH, RT.
			cm	kg	cm	cm	cm	cm	cm	cm
Under-weight	7	25 to 51	163.4	45.0 to 54.8	23.9	16.6	23.5	26.7	30.8	32.3
Average-weight	7	25 to 52	164.8	53.5 to 69.9	25.4	17.9	27.6	28.3	31.8	35.9
Over-weight	7	25 to 57	164.5	76.2 to 112.0	27.2	22.5	33.4	33.0	36.4	40.0

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containing 85 to 90 grams of protein per day and food to provide a total deficit of about 800 calories per subject per day. The ratios of fat to carbohydrate used varied widely but because of the caloric limitation, most of the protein was obtained from foods of animal origin. The mean of each measurement is reduced with weight reduction but the most rapid change is seen in the girth of the upper arm.[7] The apparent

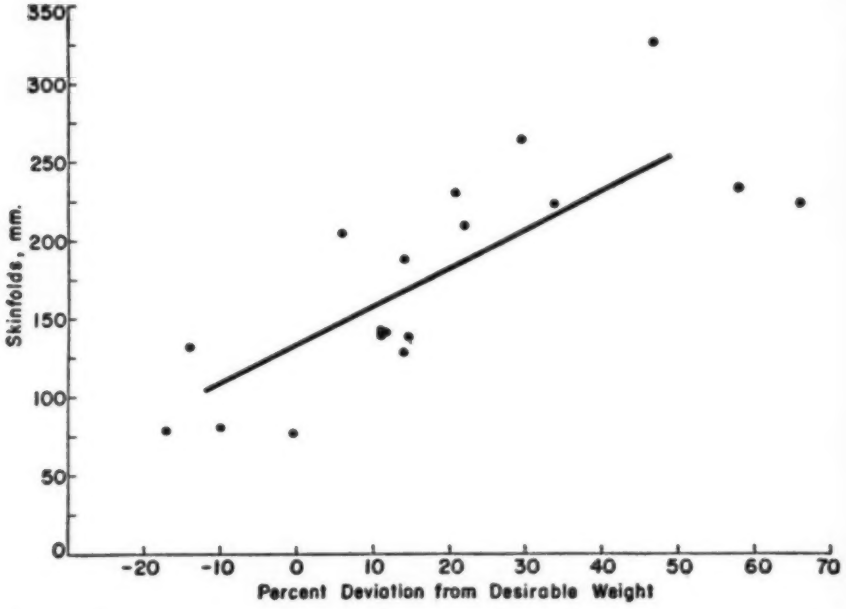

FIG. 1. RELATION OF THE SUM OF SKINFOLD MEASUREMENTS TO THE ESTIMATED DEVIATION FROM DESIRED WEIGHT OF 18 SUBJECTS.

increases in size of the antero-posterior chest, the bi-iliac and bi-trochanter widths in some subjects who lost a minimum amount of weight is of some interest and may reflect the quality of the diet previous to reduction which was known to be low in protein and certain nutrients associated with protein in food.[8] Biskind ('44) observed that there was a decrease in the size of certain of the fat pads particularly over the hips without much change of weight in subjects given a therapeutic dose

[7] *Cf.* J. Brožek, 1953, Thigh girth and nutritional status. Human Biol., *25*: 159-162.

[8] Editor's Note: Some apparent increments may reflect the variability present in all repeated measurements.

of a vitamin B mixture. Patients with a history of a poor diet consisting largely of refined carbohydrate have been observed who, when transferred to a diet high in animal protein and adequate in all known nutrients, have shown a prolonged retention of nitrogen during weight

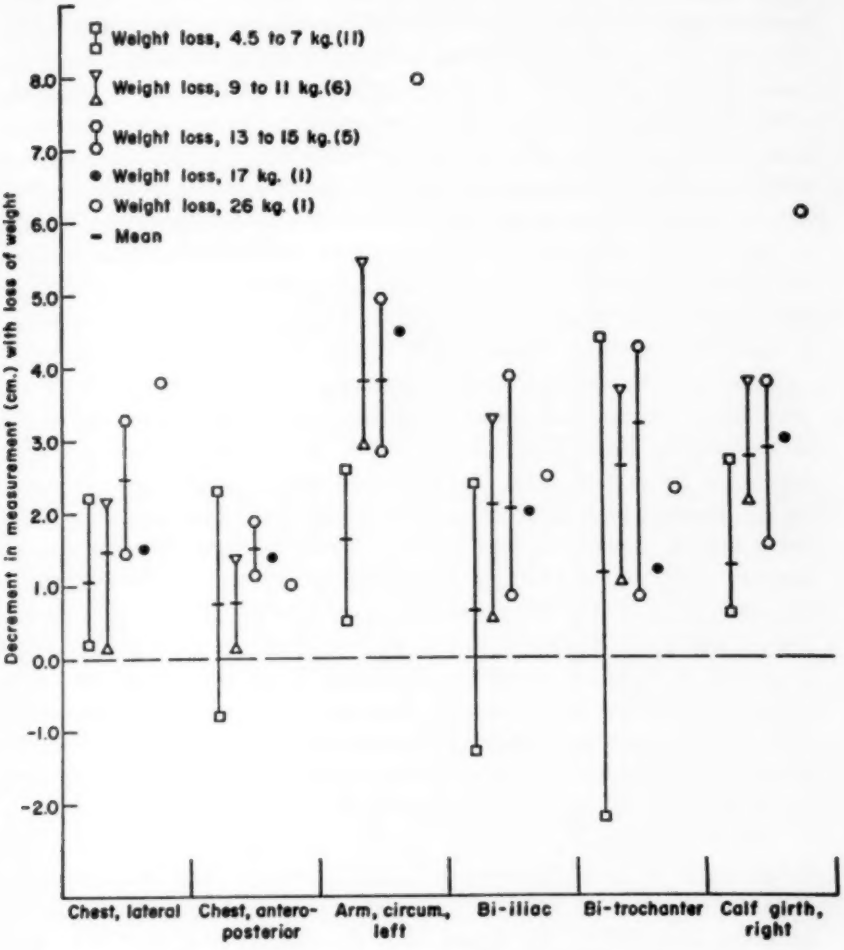

FIG. 2. RANGE OF CHANGE IN EACH OF 6 BODY MEASUREMENTS FOLLOWING WEIGHT LOSSES OF FROM 4.5 TO 26 KG.

loss and marked figure changes not entirely explained by the reduction of fat pads (Ohlson *et al.*, '55). A spontaneous increase in activity followed weight reduction in these cases suggesting a previous malnutrition in spite of overweight.

DISCUSSION

There are only a few comments which can be made on the data presented. The White women of the two communities studied were quite different in physical build and the Michigan sample appeared to be considerably larger both in skeletal measurements of breadth and in fatness. Except for height and weight, there are almost no physical measurements of women of adult age groups which may be compared with this series. Women from both states in the age period 30 to 59 were somewhat taller and heavier than reported by Bayer and Gray in 1934 for working women in England and a number of areas of the United States. The sample of Minnesota White women compared rather closely in girth of upper arm and calf with the Bayer and Gray sample, particularly in the 30 and 60 year age group, but women from Michigan were consistently larger. Both Minnesota and Michigan women tended to have smaller chest measurement except for the 50 to 59 age group.

Most of the reports cited above were published before 1931 and since there was a trend toward a steady increase in height and weight in the various series from 1912 to 1931, it is probable that this study measures, in part at least, the apparent trend toward greater stature in the population as a whole. Height and weight as reported in this study also are greater in both samples and at all ages than heights and weights reported by O'Brien and Shelton in 1941 in their study of measurements of 10,042 women for purposes of pattern construction. Only about 5% of the latter sample were selected from the North Central area and 4 of the 8 areas sampled were from the Southeast. Data reported by states would suggest that important state differences may exist. Techniques for measuring height were such that the O'Brien and Shelton series might result in slightly lower values for height than would be obtained by the procedures reported in this paper.

Other than those previously quoted, the only other extensive published study of measurements of adult women is that of Randall and Munro ('49) on Army women from the ages of 18 to 39. Unfortunately data are included in the report only through age 30, and this study, like that of O'Brien and Shelton was done for purposes of pattern construction, and except for height and weight, the measurements taken do not compare directly with those used in these observations. A limited number of measurements of subjects in the adult age brackets have been recorded on special groups. Angel ('49) measured the height, weight,

transverse and antero-posterior chest, and bi-iliac and bi-trochanter width of a series of obese women, and Trotter and Gleser ('51) made similar measurements on cadavers of the Terry Collection. In so far as comparable age data could be separated, the figures reported here are within the ranges recorded by these investigators.

This paper has been presented as an interval report, since the work, particularly with the Michigan series, is being continued with plans for serial measurements of the original sample. It is apparent that it is not possible to generalize from the samples studied to other population segments even with the same communities. However, the measurements made appear to have some merit in determining both build and fatness. The addition of selected skin fold measurements further defines fatness as related to body build.

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OBESITY AND DISEASE

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IN recent years weight reduction programs have been widely advocated as a preventive measure against heart disease and diabetes. The basis for these programs lies partly in life insurance studies. Overweight persons, limited to substandard life insurance because of excess weight, were found to have a higher mortality than persons accepted for standard insurance (Armstrong *et al.*, '51). Men markedly overweight had a mortality of 79% above the standard risk group as compared with 42% for those who were moderately overweight, and among women the increased mortality in excess of the standard risk group was 61% for markedly overweight and 42% for moderately overweight. The study also indicated that the excess mortality is due largely to a higher death rate from the degenerative diseases, particularly from cardiovascular diseases and from diabetes. Deaths due to diabetes, for example, showed more than three times the expected diabetes mortality.

In addition to insurance studies, other data are available which show that the prevalence of conditions such as hyperglycemia and high blood pressure increase with the degree of excess weight. The findings of Joslin and his associates ('52) indicated a marked influence of overweight on the development of diabetes. A review of 3,000 clinical records disclosed that 62.7% of males and 67.4% of females showed evidence of overweight at onset of disease. With regard to high blood pressure, Master, Dublin, and Marks ('50) surveyed 74,000 industrial workers and found that at every age and in both sexes there was an increase in average blood pressure with increase of body weight for a given height.

It is worth noting that these studies of the relationship of obesity to health and disease all measure "obesity" in terms of departure of actual weight from a height-weight standard. Such measurements do

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not differentiate between the effects of the fat, fluid, bone, and muscle components of the body upon weight status of persons of a given height. The departure from a height-weight standard may in some instances be due to body components other than body fat. This possibility is suggested in reports by a number of investigators. A study by Welham and Behnke ('42) concluded that, "according to standard height-weight tables, the majority of the football players could be classified as unfit for military service, and as not qualified for first class insurance by reason of overweight." Actually, overweight in these men was due largely to body components other than body fat. A necropsy study by Spain and others ('53) with special reference to somatotypes (body build classifications according to Sheldon *et al.*, '40) showed that of 38 persons whose deaths were due to coronary heart disease, 24 were classified as dominant mesomorphs (tendency toward muscularity). Gertler and his associates ('51) in clinical studies on young adults with coronary heart disease also found more dominant mesomorphs than endomorphs. Robinson and Brucer ('40) studied the relationship of obesity and body build to hypertension and concluded that whereas body build is an important predisposing factor, obesity as such was a small factor.*

Morbidity, as well as additional mortality, investigations, are needed to clarify the significance of departures from "normal" body weight. A Multiple Screening Project conducted at D. C. General Hospital in Washington, D. C. from January 23, 1952, to October 24, 1952, afforded an opportunity to study the relationship of various weight evaluation methods to the presence or absence of disease. Other aspects of this multiple screening project have already been reported (Kurlander *et al.*, '54, '55). Four methods of measuring fat were used, varying in the manner in which they included body components other than body fat. The criteria were:

1. Gross body weight,
2. Standard Height-Weight,
3. Pryor Width-Weight,
4. Skinfold thickness.

Each of the methods shows a different degree of crudeness, as far as obesity is concerned, since other components of total body weight enter in varying degrees. The standard height-weight is the earliest and still

* Editor's Note: For a discussion of "Obesity and heart disease" see A. Keys, 1955, J. Chron. Dis., *1*: 456-461.

the most commonly used method for measuring "obesity." The widely used tables of standard weights for age, sex, and height resulted from the Medico-Actuarial Mortality Investigation (Association of Life Insurance Medical Directors and the Actuarial Society of America, '12) of policy holders accepted for insurance in the United States and Canada between 1885 and 1909.

The Pryor ('40) width-weight standards call for an objective measure of the contribution of the body structure to total body weight and take into consideration the width of the hips and chest as well as the height of the subject. Thus this method better measures obesity since it considers lateral development in addition to height. The standard weights shown in the published Pryor width-weight tables were predicted from a multiple-regression equation in terms of height, bi-iliac diameter and the lateral thoracic diameter for a given age and sex.

In the D. C. General Hospital Multiple Screening Project a wooden caliper with a sliding metal arm was used to record the width of the chest and hips. The width of the chest was measured at approximately the nipple level. In taking the measurement, the arms of the caliper were pressed together until they touched the body on both sides without pressure.* The instructions for the measurement of the hips were to measure with firm pressure the greatest width at the crest of the ilium. Subjects were required only to remove their outer garments.

The skinfold thickness technique used was essentially as recommended by Brožek and Keys ('51). Measurements of the thickness of the skinfold were made at three sites: midway on the posterior line of the upper arm, above the iliac crest (in the midaxillary line), and below the left scapula. These sites were selected since they did not require that the screenees disrobe and were suggested as appropriate for surveys by Keys and Brožek ('53).

The skinfolds were measured by a caliper furnished by Dr. Keys of the University of Minnesota in 1952. The area of the contact points of this caliper was 20 square mm and the opening pressure was 530 gms. An index of body fat was obtained by averaging the three skinfold thickness values.

In the D. C. General Hospital Multiple Screening Project, screening tests and physical examinations were given to persons who applied to the admitting and emergency office for hospital or outpatient care. A

* Editor's Note: The thoracic diameter, when measured without pressure, includes also the subcutaneous adipose tissue.

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total of 964 persons were examined of whom 827 or 86% were Negro. In order to simplify interpretation of the data and because so few whites were included, only the results on Negroes were used in this obesity study.

The obesity classifications were related to the results of diagnostic investigations. Diagnostic criteria for heart disease and hypertension have been described in detail in previous papers (Kurlander *et al.*, '55). For each of the four obesity measures, "obese" persons were somewhat arbitrarily defined as those falling in the upper fifth of an array of the measurements obtained. For the Standard Height-Weight and the Pryor Width-Weight estimation procedures, percentage deviations from the standard shown in the tables were used. These percentage deviations were arrayed from largest to smallest and the upper 20% of the distribution considered as overweight. While this is not an entirely satisfactory definition of overweight, it was the only procedure that could be uniformly applied since there were no adequate standards for total body weight or skinfold thickness.

WEIGHT MEASURES AND CARDIOVASCULAR DISEASE

The sample consists of 643 persons with all four measures of obesity and a complete diagnostic work-up for cardiovascular disease. As judged by the standard height-weight tables, the 198 males in this group tended to be somewhat underweight, with 129 below the standard and only 69 at or above their standard weight. On the other hand the 445 females appeared, as a group, to be overweight with only 184 below standard weight and 261 at or above.

In order to study the relationship of obesity to disease, rheumatic heart disease, syphilitic heart disease and peripheral vascular diseases were included in the negative group since in general there appears to be little justification for relating these conditions with obesity. In considering relationship to heart disease, persons with hypertension alone were included in the non-heart disease or negative group.

The results of applying the four methods for determining obesity status to the 198 males (46 with heart disease, 20 with hypertension) are shown in Appendix I, while the values obtained for 445 females (93 with heart disease, 52 with hypertension) are shown in Appendix II.

Table 1 contains the crude and age-adjusted rates of heart disease observed in obese and normal or thin males when four different methods of designating the obese segment of the population are used. Age adjust-

ment of these rates was desirable, since some of the difference in the prevalence of disease observed in the two groups was due to a greater average age in the obese group and since heart disease is more prevalent in the older age groups. This tended to magnify differences in prevalence. Due to the small number of cases involved, data for hypertension among males are not shown.

It will be noted that actual weight, which of course includes all body components, differentiates those persons with heart disease from those persons without heart disease about as well as the other two methods of designating overweight. After adjustment for age differences, the 20% of the males most overweight had a prevalence of heart disease

TABLE 1

Crude and age adjusted rates of heart disease in Negro male patients identified as obese by four different methods of obesity classification

METHOD	OBESE (N = 40)[1]		NORMAL OR THIN (N = 158)	
	Percent with Heart Disease		Percent with Heart Disease	
	Crude Rate	Age Adjusted Rate	Crude Rate	Age Adjusted Rate
Actual weight	45.0	38.7	17.7	18.4
Standard height-weight	45.0	40.0	17.7	18.3
Pryor width-weight	42.5	38.5	18.4	18.5
Skinfold thickness	25.0	22.1	22.8	23.6

[1] Upper "fifth" of participants were designated obese.

over twice as great as the remaining 80%. *On the other hand, the skinfold thickness measurement which primarily measures body fat showed no direct relationship to the prevalence of heart disease.* These data seem to support a hypothesis that among males it is body components other than body fat that are associated with the excess heart disease mortality among overweight observed in life insurance studies when overweight was defined by the height-weight method.

The data presented in table 1 provide no evidence as to relationship between obesity and heart disease. It is quite likely that some persons with disease are thin because weight reduction is part of the treatment for the disease or maybe the effect of the disease itself. It would have

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been desirable to have applied the obesity measures before heart disease or hypertension developed to the point where it might have affected weight status—or even better, before the disease occurred. Some information can be gained by studying separately those males who were previously unaware of their heart disease and whose illness was previously unknown to the Outpatient Department of the D. C. General Hospital. In these patients presumably the heart disease had less opportunity to affect the individual's weight status. There were 22 previously unknown cases out of the total of 46 shown in table 1. The results are shown in table 2. While the numbers involved are small, the results are similar to those given in table 1 and suggest that body fat may not be important in contributing to the presence of heart disease.

TABLE 2

Previously unknown heart disease in Negro males

METHOD	OBESE (N = 40)	NORMAL OR THIN (N = 158)
	Percent with previously unknown heart disease	Percent with previously unknown heart disease
Actual weight	17.5	9.5
Standard height-weight	20.0	8.9
Pryor width-weight	15.0	10.1
Skinfold thickness	10.0	11.4

Tables 3 and 4 contain the crude and age adjusted rates of heart disease and hypertension observed in 445 Negro females classed as obese and normal or "thin." Here the age distributions of the two groups were quite similar so that the age adjustment of the percentages has little effect. For heart disease, the differences were small and the prevalence was not consistently higher in the overweight groups. On the other hand, the prevalence of hypertension in the overweight group was nearly twice as high in comparison to the normal or underweight group. This relationship was about the same, regardless of the obesity measure used. Of the 93 cases of heart disease among the females, 28 were previously unknown. When these are considered separately, as shown in table 5, prevalence is somewhat higher in the overweight as compared to the normal or underweight groups. These differences were about the same, however, regardless of the obesity measure used.

TABLE 3

Heart disease in Negro females

METHOD	OBESE (N = 89)		NORMAL OR THIN (N = 356)	
	Percent with heart disease		Percent with heart disease	
	crude rate	Age adjusted rate	crude rate	Age adjusted rate
Actual weight	24.7	24.4	19.9	19.8
Standard height-weight	21.3	22.3	20.8	20.3
Pryor width-weight	19.1	19.7	21.3	21.1
Skinfold thickness	27.0	25.0	19.4	20.0

TABLE 4

Hypertension in Nego females

METHOD	OBESE (N = 89)		NORMAL OR THIN (N = 356)	
	Percent with hypertension		Percent with hypertension	
	crude rate	Age adjusted rate	crude rate	Age adjusted rate
Actual weight	18.0	17.6	10.1	10.1
Standard height-weight	18.0	18.3	10.1	11.6
Pryor width-weight	18.0	18.3	10.1	10.1
Skinfold thickness	18.0	16.9	10.1	10.3

TABLE 5

Previously unknown heart disease in Negro females

METHOD	OBESE (N = 89)	NORMAL OR THIN (N = 356)
	Percent with previously unknown heart disease	Percent with previously unknown heart disease
Actual weight	9.0	5.6
Standard height-weight	7.9	5.9
Pryor width-weight	7.9	5.9
Skinfold thickness	9.0	5.6

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CONCLUSIONS

Data obtained from the D. C. General Hospital Multiple Screening Project throw some doubt on the role of body fat in contributing critically to the development of heart disease among males. While the numbers involved were not large and were confined to a Negro population, the results were consistent with the hypothesis that body components other than body fat are associated with excess mortality from cardiovascular disease observed in life insurance studies of overweight men. However, among females no such evidence was obtained.

The methodology used in this study is fairly simple and easily applied. The findings should be verified by similar studies in other population groups. Moreover, it seems important that more longitudinal studies dealing with the relationship of obesity to the development of disease be instituted.

1. Much of our knowledge regarding the role of obesity in the etiology of disease stems from studies in which "obesity" was defined as departure of body weight from a height-weight standard.

2. A number of studies suggest that some (or all) of the association between weight and disease may actually be due to body build rather than to obesity.

3. A study is reported here in which obesity was defined by four criteria, ranging from measures which tended to include all body components(*e.g.*, body fat, bone, muscle) to those which tended to include only body fat. The prevalence of heart disease and hypertension was compared in obese and normal or "thin" persons.

4. For males, when measures of obesity which tended to include only body fat (*i.e.*, skinfold thickness) were used, there was no relationship observed between heart disease and obesity. When measures of obesity which included other body components were used there was a pronounced relationship between heart disease and obesity.

5. In females about the same relationship between heart disease and obesity and between hypertension and obesity was observed regardless of the measure of obesity used.

6. It is concluded that the results obtained for males behaved in a fashion consistent with the hypothesis that it is body components other than body fat that are associated with the excess mortality as observed in life insurance studies of overweight men. For females, however, no

evidence was obtained which suggested that body components other than body fat have been responsible for the increased morbidity and mortality observed in the overweights as defined by the standard height-weight tables.

7. It is suggested that the methodology used here be applied in other studies and that these findings be verified. Considerable emphasis should be placed upon longitudinal studies of the relationship between body fat and the development of disease.

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APPENDIX I

Negro males. Total group and those with diagnosed heart disease or hypertension

HEART DISEASE											
Actual Weight			Standard Height-Weight			Pryor Width-Weight			Skinfold		
Weight (Pounds)	Number Tested	Number Diagnosed	Relative Body Weight*	Number Tested	Number Diagnosed	Relative Body Weight*	Number Tested	Number Diagnosed	Average Skinfold (mm)	Number Tested	Number Diagnosed
Total	198	46	Total	198	46	Total	198	46	Total	198	46
240 & over	6	3	160–169	4	2	130–139	3	1	60–64	–	–
230–239	1	1	150–159	2	1	120–129	6	4	55–59	–	–
220–229	1	0	140–149	0	0	110–119	9	4	50–54	–	–
210–219	5	2	130–139	3	2	100–109	29	9	45–49	–	–
200–209	7	4	120–129	14	6	90– 99	72	14	40–44	–	–
190–199	5	2	110–119	15	7	80– 89	65	12	35–39	3	2
180–189	11	5	100–109	31	4	70– 79	12	2	30–34	2	2
170–179	13	2	90– 99	65	15	60– 69	2	0	25–29	4	0
160–169	19	5	80– 89	45	6	50– 59	0	0	20–24	8	2
150–159	21	4	70– 79	15	3				15–19	22	4
140–149	37	6	60– 69	4	0				10–14	44	14
130–139	35	5							5– 9	104	22
120–129	19	4							Less than 5	11	0
110–119	13	3									
100–109	3	0									
90– 99	2	0									

* Shown as a percentage of the standard.

HYPERTENSION

Actual Weight			Standard Height-Weight			Pryor Width-Weight			Skinfold		
Weight (Pounds)	Number Tested	Number Diagnosed	Relative Body Weight*	Number Tested	Number Diagnosed	Relative Body Weight*	Number Tested	Number Diagnosed	Average Skinfold (mm)	Number Tested	Number Diagnosed
Total	198	20	Total	198	20	Total	198	20	Total	198	20
240 & over	6	2	160–169	4	1	130–139	3	0	60–64	–	–
			150–159	2	1	120–129	6	1	55–59	–	–
230–239	1	0	140–149	0	0	110–119	9	1	50–54	–	–
220–229	1	0	130–139	3	0	100–109	29	2	45–49	–	–
210–219	5	0	120–129	14	0	90– 99	72	7	40–44	–	–
200–209	7	0	110–119	15	2	80– 89	65	8	35–39	3	0
190–199	5	0	100–109	31	3	70– 79	12	1	30–34	2	0
180–189	11	2	90– 99	65	5	60– 69	2	0	25–29	4	0
170–179	13	0	80– 89	45	6	50– 59	0	0	20–24	8	0
160–169	19	5	70– 79	15	2				15–19	22	3
150–159	21	1	60– 69	4	0				10–14	44	6
140–149	37	2							5– 9	104	10
130–139	35	5							Less than 5	11	1
120–129	19	2									
110–119	13	1									
100–109	3	0									
90– 99	2	0									

* Shown as a percentage of the standard.

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APPENDIX II

Negro females. Total group and those with diagnosed heart disease or hypertension

HEART DISEASE

Actual Weight			Standard Height-Weight			Pryor Width-Weight			Skinfold		
Weight (Pounds)	Number Tested	Number Diagnosed	Relative Body Weight*	Number Tested	Number Diagnosed	Relative Body Weight*	Number Tested	Number Diagnosed	Average Skinfold (mm)	Number Tested	Number Diagnosed
Total	445	93	Total	445	93	Total	445	93	Total	445	93
250 & over	15	6	200 & over	5	2	170 & over	1	–	60–64	1	1
240–249	5	1	190–199	2	0	160–169	1	–	55–59	1	0
230–239	9	1	180–189	6	2	150–159	3	1	50–54	7	2
220–229	7	2	170–179	9	3	140–149	13	5	45–49	3	0
210–219	8	2	160–169	10	3	130–139	12	2	40–44	20	9
200–209	20	6	150–159	16	2	120–129	29	7	35–39	25	5
190–199	13	3	140–149	23	5	110–119	42	4	30–34	34	8
180–189	20	1	130–139	28	3	100–109	102	26	25–29	38	7
170–179	37	14	120–129	40	10	90– 99	127	29	20–24	61	15
160–169	43	9	110–119	46	16	80– 89	77	13	15–19	68	17
150–159	33	8	100–109	76	13	70– 79	35	6	10–14	78	16
140–149	39	10	90– 99	75	19	60– 69	3	–	5– 9	102	12
130–139	49	11	80– 89	58	7				Less than 5	7	1
120–129	49	6	70– 79	39	4						
110–119	47	7	60– 69	11	4						
100–109	27	1	50– 59	1	–						
90– 99	15	4									
Less than 90	9	1									

* Shown as a percentage of the standard.

HYPERTENSION

Actual Weight			Standard Height-Weight			Pryor Width-Weight			Skinfold		
Weight (Pounds)	Number Tested	Number Diagnosed	Relative Body Weight*	Number Tested	Number Diagnosed	Relative Body Weight*	Number Tested	Number Diagnosed	Average Skinfold (mm)	Number Tested	Number Diagnosed
Total	445	52	Total	445	52	Total	445	52	Total	445	52
250 & over	15	1	200 & over	5	0	170 & over	1	0	60–64	1	0
240–249	5	1				160–169	1	0	55–59	1	0
230–239	9	4	190–199	2	1	150–159	3	0	50–54	7	1
220–229	7	2	180–189	6	0	140–149	13	3	45–49	3	1
210–219	8	1	170–179	9	2	130–139	12	4	40–44	20	5
200–209	20	5	160–169	10	4	120–129	29	5	35–39	25	5
190–199	13	1	150–159	16	4	110–119	42	5	30–34	34	4
180–189	20	2	140–149	23	3	100–109	102	11	25–29	38	8
170–179	37	6	130–139	28	5	90– 99	127	18	20–24	61	6
160–169	43	2	120–129	40	5	80– 89	77	5	15–19	68	6
150–159	33	6	110–119	46	4	70– 79	35	0	10–14	78	9
140–149	39	4	100–109	76	8	60– 69	3	1	5– 9	102	6
130–139	49	6	90– 99	75	5				Less than 5	7	1
120–129	49	5	80– 89	58	7						
110–119	47	4	70– 79	39	3						
100–109	27	1	60– 69	11	0						
90– 99	15	0	50– 59	1	1						
Less than 90	9	1									

* Shown as a percentage of the standard.

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BODY WEIGHT: FACTS FROM LIFE INSURANCE RECORDS

BY HERBERT H. MARKS

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THE simplest objective facts on applicants for insurance that are easily and routinely obtained and are of the utmost value are their height and weight. Measurements of chest and abdominal girths have been available and used, and, as will be noted later, measurements of spine length were collected by one company. But their usefulness has been entirely secondary to the more voluminous and valuable data on heights and weights. The latter items of measurement permit ready classification of applicants for purposes of mortality investigations. The resulting body of information on the relationship of body weight to longevity has been of great significance to medicine and public health. Particularly is this true with regard to overweight, which is recognized as one of the principal impairments among persons applying for insurance and is associated with the early onset of degenerative diseases, particularly arteriosclerotic conditions affecting the heart and circulatory system.

It is hard for us to appreciate that a century or more ago, when life insurance began its long period of expansion, the well nourished stout man was looked on with favor as the best risk for life insurance. In those days the wasting diseases like tuberculosis and other acute infectious diseases were chiefly responsible for the very high death rates that prevailed in the population. In the absence of any sound medico-actuarial studies, the facts on the long-term outlook were unknown. How much this situation has changed will be developed in the course of these remarks.

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DEVELOPMENT OF HEIGHT-WEIGHT TABLES FROM LIFE INSURANCE RECORDS

Actually, figures on the relationship between body weight and other body measurements go back scarcely a century. The earliest insurance compilations of data on body weight were based upon small numbers of cases and obviously could give no accurate picture of the variations by height and age (*Medico-Actuarial Mortality Investigation*, vol. 1, '12, p. 11; Dingman, '46).

The first table based upon a considerable volume of statistics which took account of age was prepared by the Association of Life Insurance Medical Directors in 1897 (cited in Shepherd, '12). It was based upon 74,162 male applicants accepted for life insurance in the United States and Canada. In 1900 the National Fraternal Congress published a similar table of heights and weights according to age based upon approximately 135,000 insured in fraternal orders in the United States and Canada (cited in *Medico-Actuarial Mortality Investigation*, vol. 1, '12, pp. 11 and 19). Shortly thereafter, similar tables were prepared by a number of European insurance companies (*ibid.*, pp. 11 and 20).

The first extensive tables for women were those brought out by Dr. Faneuil S. Weisse ('12) of the Mutual Life Insurance Company of New York, in 1908. These tables were based upon height and weights of about 60,000 cases insured over the previous decade. The records for 25,000 of these women were obtained from the Mutual Life and the balance of 35,000 were supplied by the New York Life Insurance Company.

On the basis of these various sources, insurance companies prepared tables for their guidance in selection of applicants. In the first large intercompany investigation of various classes of risks in this country, known as the *Specialized Mortality Investigation* and published in 1903, appeared a table of weights covering a broad range of "normals" which was derived from these earlier studies, and, in addition, three other weight groups were defined, one for underweights and two for overweights of varying degree.

The tables of average weight for height which have been in vogue for over 40 years in this country as well as in many others were derived from the next intercompany study known as the *Medico-Actuarial Mortality Investigation* ('12-'14). This was a broad study covering the relationship of build to mortality and of the mortality associated with

a selected list of impairments and occupations among persons accepted as standard risks. The results of this study appeared in a series of volumes issued between 1912 and 1914. A goodly part of the first volume is devoted to the detailed facts on heights and weights of the insured persons. The data on men were derived from samples of the records of standard lives during 1885 to 1900 inclusive. The number of such cases totaled 221,819. The data on women were obtained partly in the same way, but since this method provided facts on only 10,000 cases, four companies provided supplementary data on women insured after 1900. The great bulk of these supplementary data were furnished by one company. In fact, of the total of the approximately 135,000 policies on the lives of women, approximately two-thirds were from that company. Heights and weights were taken in ordinary indoor clothing, with shoes on. From this material graduated tables of heights and weights were prepared for men and for women, and these have been in wide use ever since.

Subsequently, about 25 years ago, in connection with the *Medical Impairment Study, 1929* ('31), another large-scale intercompany investigation, height-weight data were again collected. The companies were requested to furnish these data on 2% of the standard cases, except at ages under 20 where data were obtained for all individuals. This yielded 667,000 cases on males and 85,000 on females. Except at ages under 25, the differences between the average weights in the old and new tables were remarkably small—so small in fact, that it was decided not to revise the standard height-weight tables except for ages under 25.

It is interesting to observe that the average heights of both men and women in the 1929 study were not significantly different from those observed in the *Medico-Actuarial Mortality Investigation* a generation earlier. The relative stability of both average heights and weights is rather significant because the level of the population to which this type of insurance was sold had gradually changed, and moreover there were significant changes in the ethnic composition of the population. In 1900, $1,000, the minimum for standard Ordinary policies, was a relatively large amount of money, so that most of the insurance of this type was issued on persons in the middle and wealthier classes. With the gradual change in the price level and the increase in wage levels, a steadily increasing number of persons in the clerical and skilled worker group purchased insurance of this kind so that they accounted for a distinctly larger proportion of persons carrying Ordinary insurance during the

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period covered by the *Medical Impairment Study, 1929*. At the same time, in the period from 1880 on, the number of immigrants rose rapidly. Between 1900 and 1914, the period of heaviest immigration, a large proportion of the immigrants were from Southern and Eastern Europe. They were generally of shorter stature and of slighter build than the earlier immigrants or the second and third generation descendants of these earlier immigrants. This is probably one of the chief reasons why the trends in build derived from life insurance records are not in agreement with those principally based upon college entrants that indicated significant increase both in stature and weight between successive generations over the same period of time.

BUILD AND MORTALITY

For this Conference, the facts of major interest are those relating to the variations in mortality, both in the aggregate and by cause, that are associated with differences in relative weight. The facts on mortality pertain generally to classifications according to either absolute or percentage deviations from average weight for height and age. The findings in broad height groups and in cases with waist girth in excess of chest girth were also ascertained. There have been two comprehensive intercompany investigations along these lines under the joint auspices of medical directors and actuaries, namely, the 1912 *Medico-Actuarial Mortality Investigation* and the *Medical Impairment Study, 1929*.[1] There is, however, useful information also in the earlier (1903) *Specialized Mortality Investigation*. In addition, there have been a large number of separate studies based upon the experience of individual companies.

Certain basic facts relating to the nature of these studies deserve emphasis.[2] (1) They are essentially long range follow-up studies based upon a considerable number of lives. (2) The initial selection of cases and the subsequent evaluation are entirely independent and the evaluation is entirely objective. (3) These studies relate to presumably healthy persons, selected after medical examination, who are in better than average circumstances, free of serious defects, and in safe occupations. They do not relate to a cross section of the general population. Insofar as certain of the more serious impairments causing rating or

[1] Another investigation of this kind has already been planned and is under way.

[2] A fuller statement on the nature, the advantages and limitations of these studies will be found in a paper by Lew ('54).

rejection for life insurance are more frequent in overweights than in persons of less weight, the results understate, relatively, the mortality associated with overweight.

The results of these investigations are presented in the form of mortality ratios which show the percentage of actual to expected deaths. This percentage relates the number of deaths that occurred among persons in a specific category to the number that would have occurred if their death rates had been the same as those experienced by age and duration among persons upon whom the mortality standard is based. Except as noted, this mortality standard relates to persons insured under standard Ordinary policies during the same period. In the more recent studies, mortality ratios were computed for each of the major causes of death, as well as for all causes.

It is recognized that classification of body build based upon height and weight alone is not completely adequate. Nevertheless, the range of variation of body weight at each height is great enough to provide significant differentiation between persons of various builds. Moreover, this classification is virtually the only one for which a substantial volume of long range data on longevity is available.

SPECIALIZED MORTALITY INVESTIGATION

The *Specialized Mortality Investigation* ('03) covered the experience of 34 companies on 98 special classes of male risks who were insured at standard premium rates after 1869 but before 1900 and traced to the policy anniversary in 1900. The mortality table used in the computation of mortality ratios was based on an English life table which was not altogether suitable because it understated the mortality ratios at the younger ages. Nevertheless, the facts in this study are instructive. There were several classes in which body build was a factor. Among the obese, the mortality was significantly above the expected except at entry ages 15 to 28. Among those with a lesser degree of overweight, the mortality ratios were generally lower than among the obese. In classes concerned with average and underweight persons, the observed mortalities were all generally below the expected.

MEDICO-ACTUARIAL MORTALITY INVESTIGATION

The *Medico-Actuarial Mortality Investigation* (vol. 2, '13) analyzed in great detail the effect of mortality in relation to build. Among males

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the unadjusted mortality ratios in detailed classes showed a fairly consistent downward trend in the ratios with advancing age for underweights and to some extent in those for average-weight men. The trend of ratios begins to shift upward by age among those slightly overweight and this was distinctly so in the case of those 15 to 20 pounds above average weight. The trend was not consistent by age in the group 25 to 30 pounds above average, but, except at the oldest ages at issue, the mortality ratios in this group were consistently above 100%. It was clear that at ages under 35 at issue the mortality figures favored those who were slightly or moderately overweight, but this did not hold true at ages beyond 35. At most ages from 35 up to about 55, the lowest mortality ratios were recorded among men 5 to 10 pounds underweight and, at ages 57 to 62, among those 15 to 20 pounds underweight. The highest ratios were generally of the order of 15 to 25% in excess of the standard, but if the class with the lowest mortality ratio is used as the base, the mortality among overweights after ages 35 ran from 30% to more than 40% higher than the minimum in the various age groups up to 56. In the oldest age group, 57 to 62, it was approximately 50% higher.

Attention was paid in this study to the causes of death according to build, but unfortunately the material considered only three broad classes, namely, those 50 pounds or more overweight, those 25 pounds or more underweight, and the group between, designated as "Standard Lives." Nevertheless, certain findings are of significance. At ages 15 to 29 at entry the highest mortality was recorded in the underweight group, and was primarily due to the mortality from tuberculosis which accounted for nearly 40% of the deaths. Even in this young age group, however, overweights had the highest mortality from diabetes, cerebral hemorrhage and apoplexy, heart disease, cirrhosis of the liver and Bright's disease. At ages 30 to 44 at entry overweights showed much the highest death rate from all causes and also from diabetes, all the cardiovascular-renal diseases and cirrhosis. The rates for the obese from the cardiovascular-renal diseases averaged more than four times that among the underweights. In this age group tuberculosis was the major cause of the small excess in the death rate of underweights as compared with overweights. At ages 45 and over the crude mortality rate was least in the underweight group and highest among the obese. The excess was most marked for diabetes where the rate among the obese was 20 times that among underweights. For cardiovascular-renal diseases, the crude death rate among the obese averaged more than double the figures recorded for the underweights.

Attention was also given in this study to the excess of abdominal girth over chest girth in relation to build (*Medico-Actuarial Mortality Investigation*, vol. 4, '14). The findings were not altogether consistent although it is evident that the mortality experience on obese men with large abdominal girth was very poor. Part of the inconsistency in the findings is believed to be the more rigorous selection of cases with excessive abdominal girth who were accepted for standard insurance.

The *Medico-Actuarial Mortality Investigation* also covered variations in the mortality experience according to body weight for females (vol. 2, '13). The number of lives was much smaller than for men, but in general, the characteristics of mortality by build paralleled that found among men; namely, at the younger ages, the record was least favorable among underweight and at the older ages was most favorable among them. In the overall picture the overweights had the highest mortality.

MEDICAL IMPAIRMENT STUDY, 1929

The next major intercompany study of build in relation to mortality was made in connection with the *Medical Impairment Study, 1929* for which the height-weight data were given previously. The mortality study was limited to males (*Supplement to Medical Impairment Study*, '32). It included those who were substandard risks on account of build. It covered the experience during 1909-1928 on those insured from 1885 to 1927. The general characteristics of build in relation to mortality found in the *Medico-Actuarial Mortality Investigation* still prevailed, namely, the mortality record was slightly unfavorable among young adult underweights, but at the older ages this group did best. In contrast, the mortality among the obese was highest in all age groups.

The high mortality among the overweights is thrown into better relief if comparison is made on the basis of the weight group with the lowest mortality ratio. The details are shown in table 1. Thus, it is found that for those 25% or more overweight, the mortality ratios were generally one and a half times that of the weight group with lowest mortality.

Analysis of the causes of death in this experience was made on the same basis used in the *Medico-Actuarial Mortality Investigation*. Because of the inclusion of a very large number of young lives, these data at ages 10 to 29 are atypical and are therefore omitted from this discussion. At ages 30 to 44 the mortality was the highest among overweights, due

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TABLE 1

Medical impairment study, 1929

Observed ratios of actual to expected mortality among male overweights and estimated ratios based upon mortality in "optimal weight" group

Experience of 32 life insurance companies, 1909 to 1927 by deviations from average weight and by age groups at issue

AGE GROUP AT ISSUE: Percent above average weight	PERCENT ACTUAL OF EXPECTED DEATHS: Observed	Estimated on basis of mortality in "Optimal weight" group *
Ages 20–29		
5% to 14%	99	106
15% to 24%	107	115
25% to 34%	134	144
35% or more	163	175
Ages 30–39		
5% to 14%	90	107
15% to 24%	120	143
25% to 34%	137	163
35% or more	137	163
Ages 40–49		
5% to 14%	97	126
15% to 24%	117	152
25% to 34%	141	183
35% or more	141	183
Ages 50–59		
5% to 14%	91	115
15% to 24%	118	149
25% to 34%	122	154
35% or more	143	181

* Ratio in weight group with lowest mortality

Ages 20–29—93%

30–39—84%

40–49—77%

50–59—79%

primarily to the cardiovascular-renal diseases and diabetes. In the underweight group the small excess of the death rate over that of standard lives is more than accounted for by tuberculosis. At ages after 45 the crude mortality was lowest among underweights and highest among overweights, and all but a small part of the excess of the mortality among the obese was due to the cardiovascular-renal diseases and diabetes. The mortality rates were all distinctly lower in this study than in the *Medico-Actuarial Mortality Investigation*, but significantly, the greatest improvement was in the respiratory diseases, especially among average and underweights, where not only the actual mortality was lowered but also the proportion of total deaths due to these causes.

Investigation was made also of the mortality among cases with abdominal measurements more than two inches greater than chest girth at full expansion. In all cases the mortality was elevated, seriously so in those markedly overweight.

STUDIES MADE AFTER 1929

In the years since 1929 we have witnessed the virtual abolition of deaths from tuberculosis among the better situated classes in the community, and in all classes, radical reduction in mortality from infectious diseases, notably pneumonia. While the mortality from these conditions still tends to be higher in underweights, their importance relative to the total mortality has diminished so greatly that when the trend in the mortality from all causes combined is considered, it is so greatly in favor of underweights as to wipe out even at the younger ages the differential in mortality that was formerly in favor of overweights. This has been brought out in a number of studies of the experience of individual companies made in recent years (Dublin and Marks, '37 and '38; Blair and Haines, '49; McCormick, '49).

A comprehensive investigation was made of the mortality experience on women according to build among those insured by the Metropolitan Life Insurance Company between 1922 and 1934 and traced to the policy anniversary in 1936 (Dublin and Marks, '37 and '38). This study showed the same trends as earlier studies on male lives, namely, relatively high mortality among young underweights; distinctly high mortality among old overweights; the most favorable build for mortality shifted from moderate overweight at the younger ages to moderate underweight at older ages. Some evidence was found that the excess mortality

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at both extremes of the weight scale was not as great in females as in males.

For tuberculosis the mortality was much higher than average among underweights and decreased with increasing weight. Among young underweights, the mortality from pneumonia and influenza was likewise higher than average for those markedly underweight. For the chronic cardiovascular-renal diseases there was a fairly steady progression of the ratios from the lowest levels in the underweight groups to the highest in overweight groups. The most striking differences were found in diabetes and diseases of the gallbladder and biliary passages. For these the upward progression of the mortality ratios with increasing weight was marked.

A special study of the mortality among very tall men showed that with respect to the relation of build to mortality these men were no different from their shorter fellows (Dublin and Marks, '36). This study, based upon the experience of the Metropolitan Life Insurance Company in 1922-1935 on men at least 6 feet 2 inches tall showed a generally higher mortality among those who were overweight than among the underweights. This was especially marked among the older men, and for them particularly the excess mortality was due principally to degenrative cardiovascular-renal diseases.

A study was made of the Metropolitan's experience on persons limited to substandard insurance solely on account of weight who were insured in the period 1925 to 1934 and traced to the insurance anniversary in 1950 (Dublin and Marks, '52). This experience covered more than 50,000 persons—26,000 men and 25,000 women. The mortality of these overweights was measured by the comparable experience for each sex among persons accepted for standard insurance. The adverse effect of overweight was evident at every period of adult life and increased with the degree of overweight.

Again, a better measure of the excess mortality of these overweights is to compare it with that of the weight group with the lowest mortality. For this purpose contemporaneous data were not available. Accordingly, the ratio for the "optimal weight" group of the *Medical Impairment Study, 1929* was used as a standard. Computations for males on this basis, given in table 2, indicate that the mortality ratio among the overweights in the new study was of the order of 200% at ages 20 to 50 and 165% at ages 50 to 59.

The excess mortality of the overweights in this study also was primarily accounted for by the high death rates from the diseases of the cardiovascular-renal system, diabetes, and liver and gallbladder disorders. Both sexes showed the same general picture.

TABLE 2

Mortality among males limited to substandard insurance because of overweight

Observed ratios of actual to expected deaths and estimated ratios on basis of mortality in "optimal weight" group

Experience of Metropolitan Life Insurance Company, Ordinary Department, issues of 1925–1934, traced to policy anniversary in 1950

AGE GROUP AT ISSUE	PERCENT ACTUAL OF EXPECTED DEATHS	
	Observed	Estimated on basis of mortality in "optimal weight" group *
20–29	180	194
30–39	169	201
40–49	152	197
50–59	131	166

* According to ratios in weight group with lowest mortality in *Medical Impairment Study, 1929*. For details see footnote to table 1.

EFFECT OF WEIGHT REDUCTION ON MORTALITY

It was possible in this study to segregate those overweights who had lost enough weight to have their rating removed and to analyze the mortality record for them. It was found that weight reduction improved the outlook for these cases. For example, among men originally limited to Substandard insurance because they were moderately overweight, the mortality subsequent to the change of rating was 113% of the standard, compared with a mortality ratio 142% for all the moderately overweight men.

MORTALITY AMONG OVERWEIGHTS IN RELATION TO SPINE LENGTH AND CHEST GIRTH

Since insurance physicians and actuaries have been well aware that many overweights, even some of the obese, live to a ripe old age, it is not surprising that search has been made for some simple means of

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identifying the "good" overweights. All these attempts have been fruitless. The major study along these lines which was thought to have great promise was based upon the criteria of physical fitness developed by Dreyer ('21), according to which a relatively long trunk appeared to be advantageous. Fortunately the Union Central Life Insurance Company had required measures of the length of the trunk of applicants. This provided the only source of data based upon a considerable volume of experience that would approximate Dreyer's criteria. Preliminary studies were made to set up the necessary standards of relative spine length according to height and age (Dublin, '23). Tests of Dreyer's criteria were applied to employees of the Metropolitan Life Insurance Company. The criteria were not successful in discriminating between the healthy and the unhealthy employees. Nevertheless, a full-scale study was conducted to test the hypothesis by the long term mortality experience on the Union Central Life Insurance Company's male policyholders (Dublin, '24 and '25). The results were rather contradictory and confusing. Tall overweights with long trunks had a somewhat lower mortality than other overweights, but this did not hold for shorter men. The only positive finding was that overweights with large chest girths had a higher mortality than the others. One may suspect that this might simply have reflected a somewhat higher average weight for the group.

MODIFICATIONS OF STANDARD WEIGHT TABLES

The evidence then is overwhelming that overweight is dangerous for health in many ways, and the shortening of life associated with it is a serious matter. Moreover, the standard of weight in middle and old age is much too generous. Suspicion about this goes back longer than is generally realized. As early as 1908 Dr. Brandreth Symonds, one of the great figures in life insurance medicine of his day, raised the question and again brought it up in his presidential address at the meeting of the Association of Life Insurance Medical Directors in 1912 (Symonds, '15). Accordingly, a resolution was passed by the Association requesting the Subcommittee in Charge of the Medico-Actuarial Investigation to work with the Actuarial Society to produce a table of weights which corresponded with the lowest mortality. We find this matter of the best weight a recurrent theme in the deliberations of life insurance medical directors and the actuaries. In 1920 Arthur Hunter, the Actuary of the New York Life Insurance Company, spoke before the Actuarial

Society on the topic "Is the Average the Same as the Normal for Weight and Blood Pressure?" His paper contains a table of "normal" weights, using the lowest mortality as a gauge, for men of average height.

Over the years there was mounting criticism of the weight tables in common use in that they ignored the disadvantages of the increase in weight with advancing age, as well as variations in bodily proportions and other factors that influence the weight of individuals. Among the attempts to satisfy this deficiency was the construction of desirable weight tables (originally designated "ideal weight" tables) for men and women by the Statistical Bureau of the Metropolitan Life Insurance Company in 1942-1943. These tables apply to all adult ages 25 and over. They are primarily based upon adjusted values of the earlier standard tables. Rather arbitrary assumptions were made in devising these tables, because of the lack, which existed then and still exists today, of more exact criteria for use in constructing tables of this kind for common use. The tables of desirable weight are generally adequate for the purpose for which they were designed, but further study of the matter is needed.

Concern about weight standards is greater today than ever before because, as the germ enemies of mankind have been nearly annihilated and the proportion of persons surviving to middle and later life has greatly increased, the chief problem in the field of health is control of the cardiovascular diseases which now account for the majority of deaths. Of particular concern are the high rates prevalent among men in their productive years. Much of this represents premature degeneration, and to that extent, efforts to prevent or slow down the process are eminently worthwhile.

SUMMARY

Life insurance records of body measurements on large numbers of men and women have been of value as the source of data for the construction of height-weight tables. Such data, collected at irregular intervals, indicate that average weights, specific for height and age, were fairly stable over long periods except at the younger ages. More current data of the kind are highly desirable.

Even more useful have been the studies of the relation of body build to mortality. The body build was characterized, principally, in terms of a deviation from the average weight for sex, age and height. The number of such studies is quite large. They include major inves-

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tigations comprising the combined experience of all the major life insurance companies as well as more numerous studies of the experience of individual companies. The period of time covered by these various investigations spans the years from post-Civil War days down to the present. Despite the long period of time covered by the insurance investigations and the variety of sources of the data, they have shown consistently that excess weight is associated with decreased vitality and longevity. Furthermore, despite changes in medical concepts and terminology, the excess mortality was found, consistently, to be due to the early onset and relatively rapid progression of diseases affecting the circulation, the excessive frequency of diabetes, in which vascular breakdown occurs earlier than in nondiabetics, and of disorders affecting the liver and gall bladder. The implications of these findings with regard to the penalty of overweight are unmistakable.

It is clear that the standards of weight long in vogue in this country and still widely used are too generous. Consequently, modification of these tables is overdue. A new study of life insurance experience, now under way, will provide the basis for new standards.

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FAT THICKNESS AND GROWTH PROGRESS DURING INFANCY

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INTRODUCTION

THE human fetus, lean until late in prenatal life, accumulates fat at so rapid a pace thereafter that the newborn infant is notable among mammals for high fat content (Widdowson '50, McCance and Widdowson '51). Fat addition continues to be rapid, from birth until some time in the first year (Stuart *et al.* '40, Reynolds '51). Thus the one-year old, not necessarily at his fattest, is as fat percentagewise as the 50-year old male (Garn and Harper '55) and in many cases far exceeds 25% fat by weight (Garn, unpublished data).

The unusual fatness of the human infant probably represents an evolutionary adaptation to the thermoregulatory problems faced by the young of a glabrous wide-ranging homeotherm. While this explanation cannot be verified directly, it is true that adjustment to low temperatures is made easier by an adequate *tela adiposa*. Besides, there is experimental evidence that fat materially reduces heat loss in the infant, and thereby minimizes the total caloric requirements (Murlin '23, p. 645).

A second problem relating to the infant's fat concerns its mobilization, availability and usage. In adults, a large proportion of the stored fat appears to be available when needed. For older children there is evidence that the amount of fat stored is directly related to size and growth progress. From Czerny and Keller ('28) to Bruch ('39) to Fry ('53), findings agree that fatter children tend to be somewhat taller, advanced in skeletal development, earlier in attaining sexual maturation,

dentally advanced and that they tend to excrete amounts of urinary 17 ketosteroids above the average for their age (Talbot '45, Talbot, Sobel, McArthur and Crawford '52). Whether the larger size and more rapid growth progress of obese children is attributable to "functional hyperpituitarism secondary to caloric hypernutrition," as Talbot puts it, is not certain. But the demonstrable relationship between the amount of stored fat and size and growth progress in childhood makes the fat a useful indicator of the "nutritive state" at that time (*cf.* Batkin '15 and later authors).

But what is the situation in infancy? How do size and growth relate to the amount of fat? Here comparable data have been lacking, to the best of our knowledge. Though there are large individual differences in the amount of fat stored by infants, it is not known for certain whether or not these differences are paralleled by comparable variations in size and growth (as in childhood). It is the purpose of the present study to examine this problem.

METHODS AND MATERIALS

The present study is based upon serial anthropometric and roentgenogrammetric data on over 300 White infants at 1, 3, 6, 9, and 12 months. All were born in Southwestern Ohio, generally to Ohio-born parents of northwestern European ancestry. Twins and triplets and infants weighing less than 2500 grams at birth were excluded from the tabulations, as were infants with congenital defects. Acutely-ill infants and those recovering from illness were not included, since such individuals are not ordinarily brought to the Fels Institute at the time of a regularly scheduled appointment (*cf.* Robinow '42, p. 159). The group then consists of clinically healthy White infants, with the developmentally immature weeded out.

Besides length (recumbent crown-heel length) and weight (nude) the following measurements were made on standardized antero-posterior roentgenograms of the left lower leg: tibial shaft length, maximum muscle breadth, and the combined medial and lateral subcutaneous fat-plus-skin thicknesses. In addition to the group means, computed in the usual way, size increments were calculated on an individual basis, for each measurement for each child.

Tibial length was selected as an index of long-bone size and growth. This measurement was taken as the maximum extent of calcification visible along the diaphysis, excluding epiphyses when present (see Maresh

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and Deming '39, Maresh '43, Kelly and Reynolds '47). Though there are advantages to measuring the fibula instead of the tibia (Day and Silverman '52, Silverman, Day and Blodi, '51) the tibia is more easily measured in the standardized A-P view. However, the two bones yield closely related though obviously not identical results (Maresh '43).

Muscle size was measured as a simple diameter: the *maximum* diameter of the calf muscle shadow at right angles to the tibial shaft. This diameter overestimates but is highly correlated with the computed true cross-section area. The measurement of muscle size used by Reynolds in 1944, namely, "the combined breadth of the two muscle masses on each side of the two bones" (Reynolds '44, p. 184) was not employed both because it underestimates the true cross-section area and because slight errors of rotation markedly affect the obtained diameter. Similarly the technique of measuring the entire lower-leg muscle area, either by cutting out and weighing the muscle "shadow" (Stuart *et al.* '40), or by planimetry (Suarez '52, p. 202) was not utilized here because the so-called "total muscle area" of the lower leg includes much that is not muscle.

The subcutaneous fat thickness, measured as described by Garn ('54), is the sum of the two separately measured diameters, medial fat (*mf*) and lateral fat (*lf*). Since sex differences in the relative size of the two deposits are not as marked in infancy as they are in adults (*cf.* Garn and Saalberg '53), combining the two values helps to minimize errors due to medial or lateral leg rotation. While averaged values could be used instead of the total reported here (*mf* plus *lf*), averaging simply divides the total by a constant, and therefore constitutes superfluous computation.

The question of enlargement, sometimes incorrectly called "distortion," has been raised in discussing radiographic measurements of this kind. Since the tube-to-film distance is constant and part thicknesses do not vary greatly, the raw measurements can be used without correction. Even if full corrections are made for variations in part thickness, which affect only the distance anode-to-median-plane, they are surprisingly small.[1] In the present study the enlargement ratio averages 102% at 1 and 3 months, and 103% at 6, 8 and 12 months. The correction factors are therefore 0.98 and 0.97 respectively. The difference (0.01) is of no practical importance in this work.

[1] The enlargement ratio is D_1/D_2 when D_1 is the anode-to-film distance and D_2 is the anode-to-median-plane distance (see Kemp, '51). The correction factor is the reciprocal of the enlargement ratio. In the present study D_1 is 914 mm and D_2 varies from 900 to 880 mm, depending on part thickness.

Throughout this paper reference is made to the leg muscle diameter and to the leg fat thickness. The reader is cautioned against extrapolating from these measurements to changes in tissue composition in the body as a whole. For, when all body components are in process of rapid change as they are in infants, a marked increase in the size of a

TABLE 1

Leg fat thicknesses and leg fat increments for boys and girls aged 1-12 months

		FAT THICKNESS PERCENTILES				
AGE	SEX	5	15	50	85	95
1 mo.	Boys	6.2 [1]	7.8	9.5	11.3	13.3
1 mo.	Girls	6.3	7.7	9.6	11.8	13.7
3 mo.	Boys	9.2	13.2	15.7	17.7	21.0
3 mo.	Girls	11.4	13.4	15.4	18.5	19.4
6 mo.	Boys	15.3	17.2	20.0	23.3	26.6
6 mo.	Girls	14.8	17.2	19.8	23.2	26.0
9 mo.	Boys	15.8	18.2	21.0	24.0	27.9
9 mo.	Girls	15.6	17.7	20.7	24.5	27.3
12 mo.	Boys	14.6	16.9	19.3	22.1	25.6
12 mo.	Girls	13.9	16.5	20.5	23.1	27.8

		FAT INCREMENT PERCENTILES				
AGE	SEX	5	15	50	85	95
1–3 mo.	Boys	1.9 [2]	3.7	5.7	7.4	9.3
1–3 mo.	Girls	2.8	4.2	5.7	7.4	8.8
3–6 mo.	Boys	0.5	2.4	4.5	7.2	9.2
3–6 mo.	Girls	0.9	2.8	4.7	6.7	10.6
6–9 mo.	Boys	—2.0	—0.6	0.8	2.3	4.1
6–9 mo.	Girls	—3.3	—0.5	0.7	2.5	4.2
9–12 mo.	Boys	—4.1	—2.8	—1.3	0.3	2.5
9–12 mo.	Girls	—3.8	—2.3	—0.9	0.8	3.5

[1] Combined medial and lateral leg fat in mm.

[2] Increment in mm.

given tissue layer may actually represent a *decrease* in the percentage contribution of that tissue to the body. Similarly, failure of a measured thickness to increase on the average does not necessarily mean that the tissue in question has failed to increase in the body as a whole. Estimates of changes in body composition have been made from the present data and will be reported in a separate communication.

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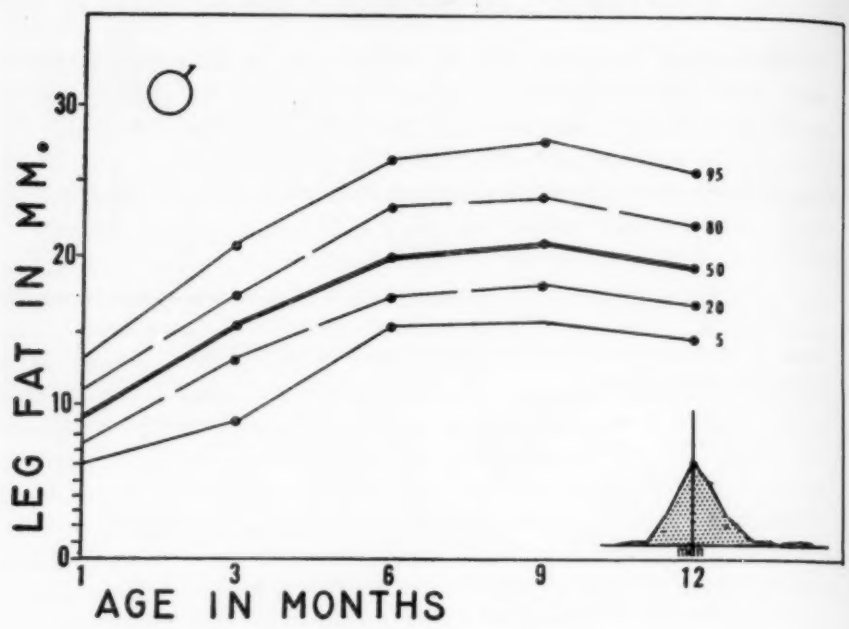

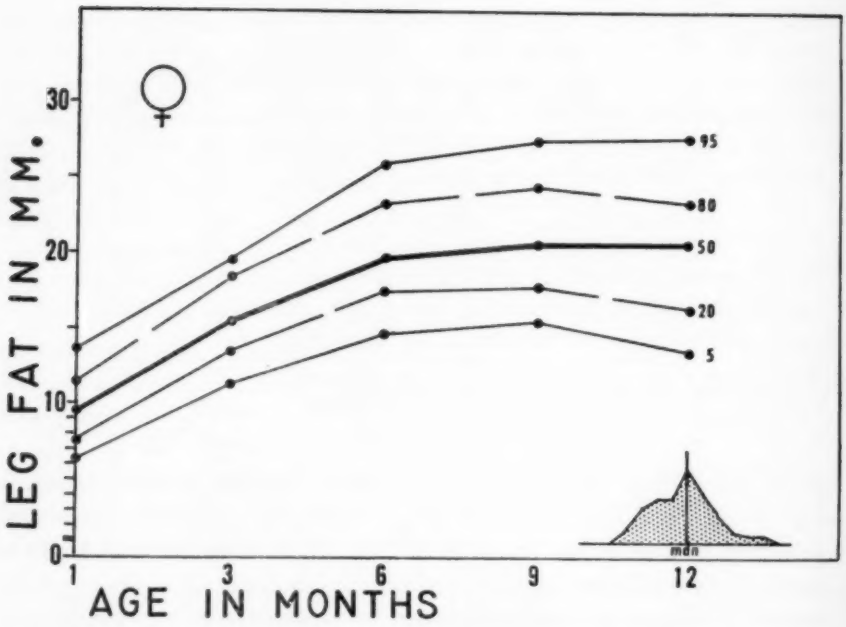

FIG. 1. Changes in the thickness of the subcutaneous fat on the lower leg from the 1st to the 12th month after birth. The heavy represents the median value, the lighter lines indicate the 5th, 20th, 80th and 95th percentiles. In both sexes the group trend is toward rapid accumulation of fat from the 1st to the 6th month.

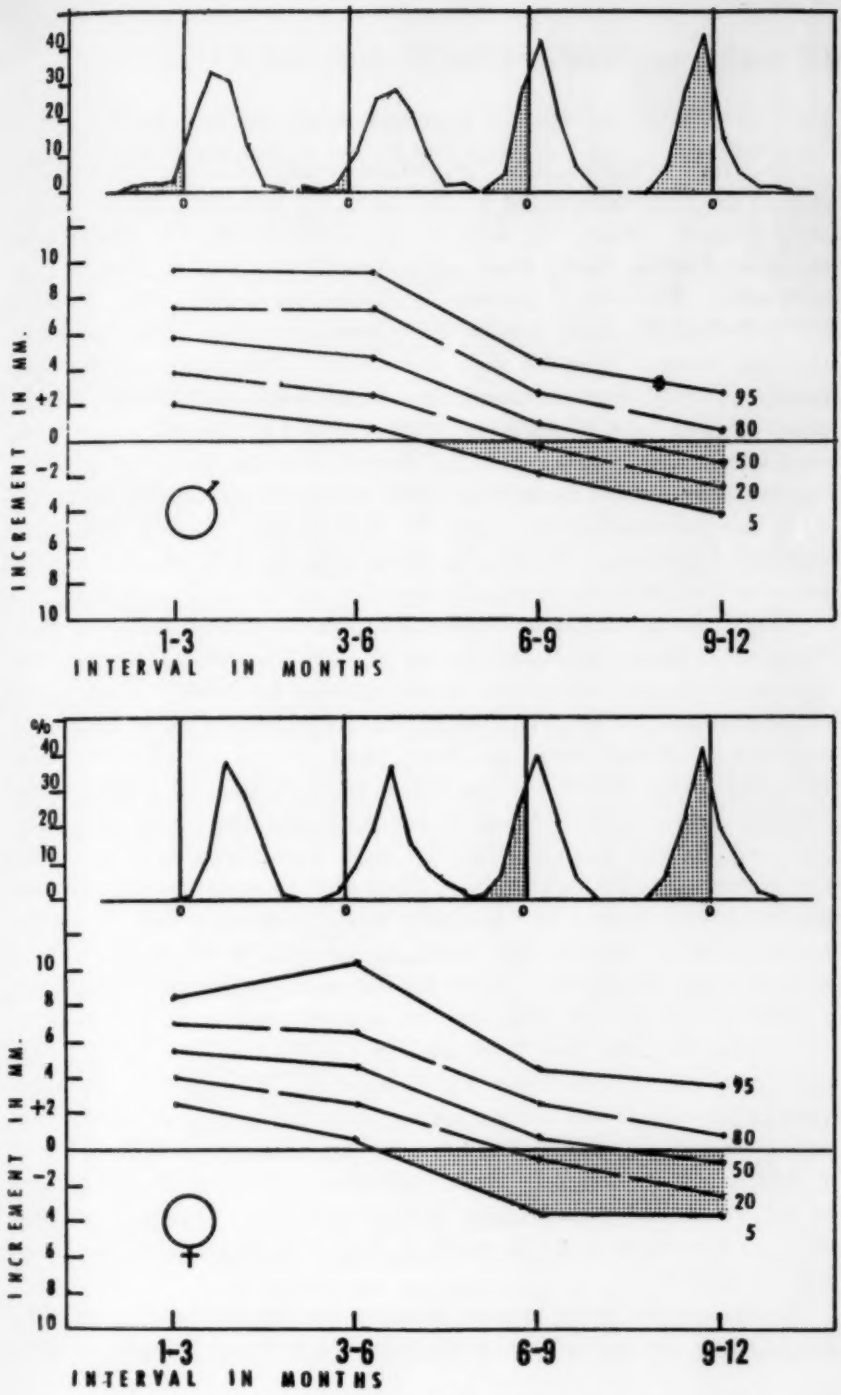

FIG. 2. Fat increments during the first year of life. Up to the 6th month all infants gain leg fat. Between the 6th and 9th month a minority have begun to lose; the majority are still gaining. Conversely between the 9th and the 12th month the majority lose fat. Compare this figure, based on individual *increments*, with the mass-data trends shown in figure 1.

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FINDINGS

As shown in table 1, and pictured graphically in figure 1, the thickness of the subcutaneous fat on the lower leg increases rapidly during early infancy. From the first to the sixth month the median fat thickness doubles, rising from approximately 9.5 mm to 19.9 mm in both sexes. The rate of increase is 2.0 mm per month. But, between the sixth and the ninth month, the percentile values change but little, the total increase being 1.0 mm, and the rate of deposition 0.3 mm per month. Finally, between the ninth and the twelfth months, the median drops slightly both in boys and girls (table 1). At all 5 age levels considered the fat distributions are skewed, with the degree of skewness varying from month to month. Thus percentiles as employed in this study are more appropriate than the more commonly used means and standard deviations. Further, in comparing fat and lean infants the series is divided at the median rather than at the arithmetic mean.

While the fat thickness percentiles given in table 1 correctly show the rapid increase in lower leg fat during the first half year, they incorrectly suggest little change in subcutaneous fat during the remainder of the first year of life. The fat increments, computed on an individual basis tell a different story. As shown in the second half of table 1, and in figure 2, the period 1–6 months is characterized by a general fat increase. But, between 6 and 9 months (when the majority of boys and girls are still gaining fat) a minority have begun to lose fat: the two trends partially balance each other and thus the median remains nearly constant from 6 to 9 months. Again, between 9 and 12 months, the majority of infants lose lower leg fat (up to 6.0 mm) while a minority are still gaining. Thus fat change is considerable during the second half of the first year, but the changes occur in both directions.

During the first year there are large individual differences in the amount of fat on the lower leg, though sex differences in thickness (not in percentage fat) are negligible. The fattest 5% of infants have nearly twice the combined lower leg fat thickness of the leanest 5% at 1, 3, 6, 9 and 12 months. Since individual differences in the amount of fat are of such a magnitude, it is of interest to determine whether they are associated with differences in length, in muscularity, or in the rate of growth.

Comparing the fatter infants (those in the third and fourth quartiles for fat) with the leaner infants (those in the first and second quartiles)

it is obvious that the former enjoy a considerable size superiority at one month. As shown in table 2 and again in figure 3, the fatter male infants average 1.3 cm longer than the leaner ones; the medians for the two groups correspond to the 65th and the 37th percentiles, respec-

TABLE 2

Length and muscle size of leaner children (Q_1 and Q_2) and fatter children (Q_3 and Q_4 during the first year of life

AGE	GROUP	CROWN-HEEL LENGTH		TIBIAL LENGTH		LEG MUSCLE DIAMETER	
		Mean (mm)	Percentile	$\bar{X}$ (mm)	Percentile	$\bar{X}$ (mm)	Percentile
1 mo.	Boys Q_1 and Q_2[1]	54.0	37	72.2	37	31.9	43
	Boys Q_3 and Q_4[2]	55.3	65 [3]	74.2	60 [4]	32.7	54
	Girls Q_1 and Q_2	53.1	40	71.5	37	30.6	42
	Girls Q_3 and Q_4	54.2	56 [4]	73.6	55 [4]	31.6	61
3 mo.	Boys Q_1 and Q_2	61.3	52	84.3	43	36.2	44
	Boys Q_3 and Q_4	61.2	47	85.2	53	36.6	52
	Girls Q_1 and Q_2	59.6	47	83.1	43	33.3	40
	Girls Q_3 and Q_4	59.6	47	84.1	57	34.4	58
6 mo.	Boys Q_1 and Q_2	67.4	48	97.0	42	39.5	50
	Boys Q_3 and Q_4	67.8	55	98.5	53	39.8	53
	Girls Q_1 and Q_2	65.9	53	95.6	48	38.2	64
	Girls Q_3 and Q_4	65.9	53	96.2	52	37.1	44
9 mo.	Boys Q_1 and Q_2	72.0	41	107.0	47	43.5	55
	Boys Q_3 and Q_4	72.2	47	107.7	51	43.4	53
	Girls Q_1 and Q_2	69.8	46	105.2	44	43.4	63
	Girls Q_3 and Q_4	70.5	56	107.1	63	41.0	43 [3]
12 mo.	Boys Q_1 and Q_2	75.7	46	116.2	44	47.7	54
	Boys Q_3 and Q_4	75.9	50	116.6	48	47.3	52
	Girls Q_1 and Q_2	74.0	49	114.7	48	47.5	57
	Girls Q_3 and Q_4	74.3	54	116.3	59	45.5	41

[1] First and second quartiles for fat.
[2] Third and fourth quartiles for fat.
[3] Difference significant at $P = .01$ or better.
[4] Difference significant at $P = .05$ or better.

tively. Similarly, the fatter female infants exceed the leaner ones by 1.1 cm, and the medians correspond to the 56th and the 40th percentiles respectively. (Both differences are significant at the 5% level or better, by the χ^2 test). But after 1 month of age comparable differences no longer exist. The differences present at 3, 6, 9 and 12 months do not

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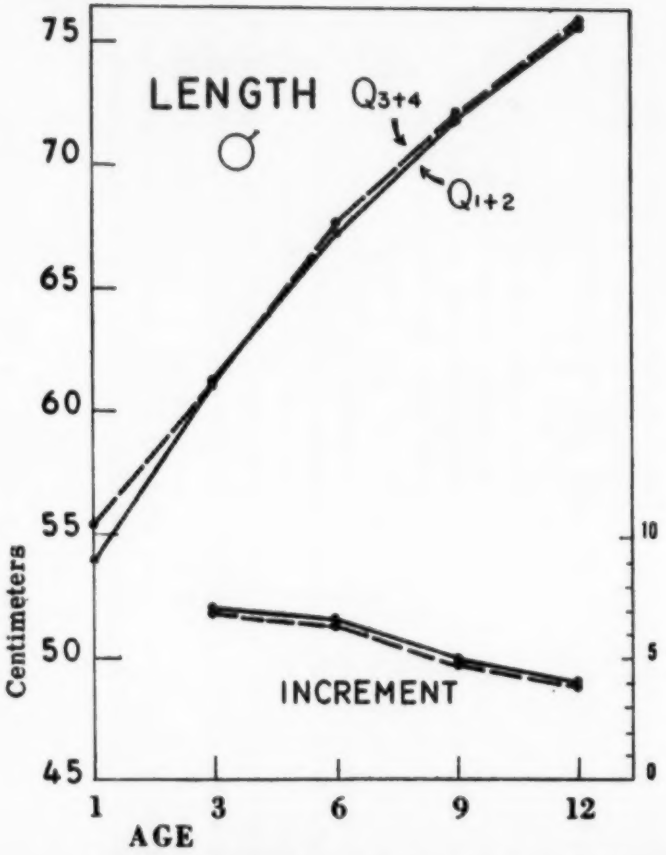


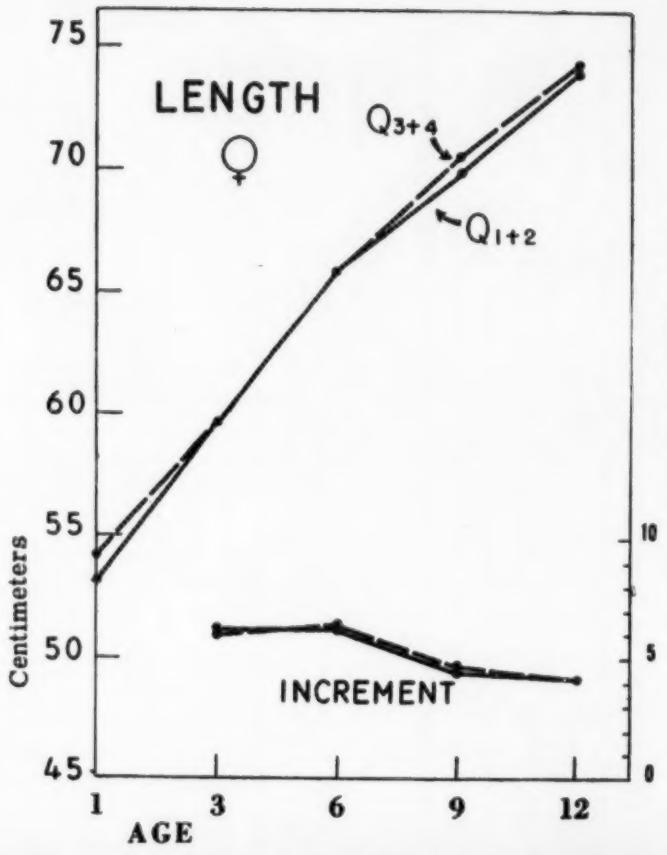
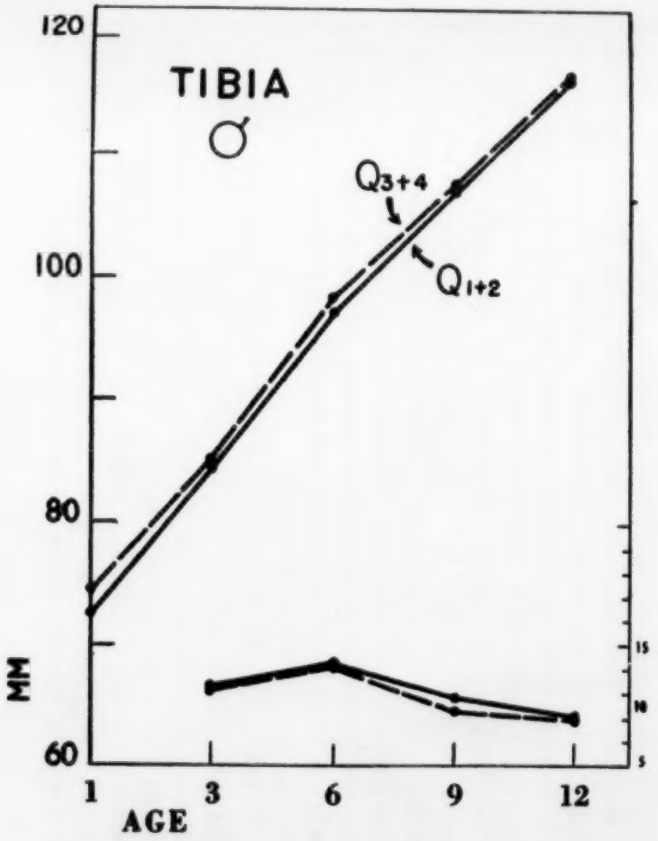


FIG. 4. Comparative length of fatter (Q_3 and Q_4) and leaner (Q_1 and Q_2) infants at 1, 3, 6, 9 and 12 months. The fatter boys and girls are significantly longer at one month, but not thereafter.

FIG. 4. Comparative length of fatter (Q_3 and Q_4) and leaner (Q_1 and Q_2) infants at 1, 3, 6, 9 and 12 months. The fatter boys and girls are significantly longer at one month, but not thereafter.



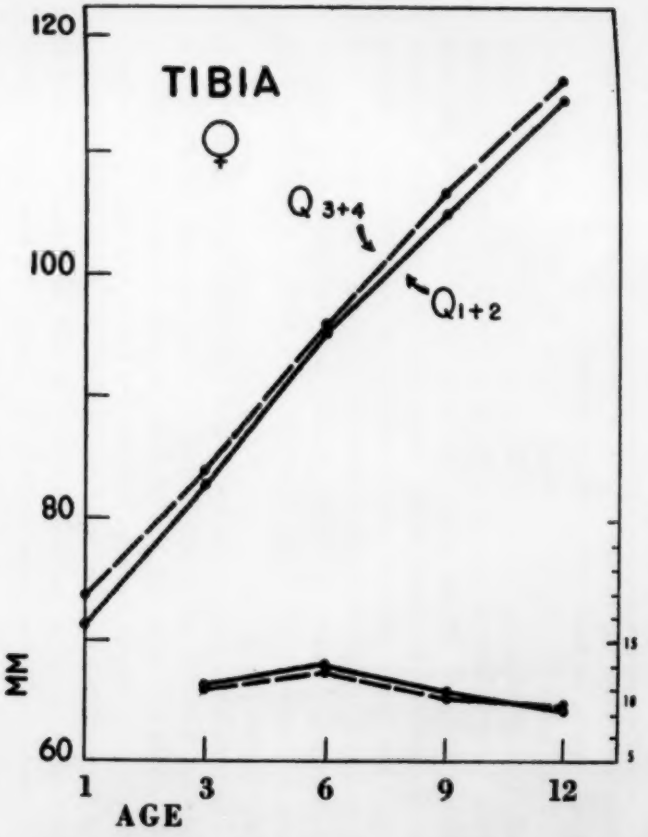


FIG. 4. Tibial shaft length of fatter (Q_3 and Q_4) and leaner (Q_1 and Q_2) infants. As with crown-heel length, the size superiority of the fatter infants attains statistical signi ficance only at one month. (Each sub-group average 70–80)

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attain statistical significance. Fat is associated with greater length at one month, in both sexes, but not beyond.

What holds for crown-heel length is true for tibial shaft length as well, thus eliminating the possibility that the initially greater length of the fatter infants is due solely to fat accumulation on the scalp and plantar surfaces. At one month the fatter boys, those in the third and fourth quartiles, are significantly longer in shaft length than the leaner boys. The fatter girls are comparably longer than the leaner girls in the extent of tibial shaft calcification at 1 month. But at 3, 6, 9 and 12 months the leaner and fatter moities are not significantly different from each other (table 2 and figure 4), even though a tendency toward slight superiority persists.

As contrasted with crown-heel length and tibial shaft length, muscle diameter does not differ significantly between lean and fat one-month-olds. With one exception, the 9-month old girls, there are no significant differences in muscle diameter between the fatter and leaner contingents and this single exception is in the reverse of the expected direction. However it should be noted in figure 6, as well as in table 2, that there is a tendency for the leaner girls to have larger leg muscle throughout the second half year. Initially the fatter girls enjoy an advantage which is not statistically significant and is not continued.

In general, then, the fatter infants exhibit a size superiority at one month, and not consistently thereafter. But the negative nature of these findings must be considered in terms of the two categories "fat" and "lean." With large individual differences in the tendency to gain or lose fat, especially during the sixth to twelfth month, it is possible for a child to be in the "fat" category at one age interval and not in another. What happens if infants initially fat, and others initially thin are followed for a full year? This has been accomplished by selecting boys and girls initially in the first quartile and the fourth quartile of the fat distribution at one month and determining their size and growth progress at 3, 6, 9 and 12 months.

As shown in table 3 and figure 6 the "fattest" (Q_4) and "leanest" (Q_1) infants differ considerably at one month. Those in the fourth fat quartile are markedly longer than those in the first fat quartile, exaggerating the trend previously noted. They also differ in muscle width, though to a less considerable degree. At three months the size gap between the "initially fat" and "initially thin" infants is narrower. At 6 months the differences are no longer significant at the 5% level,

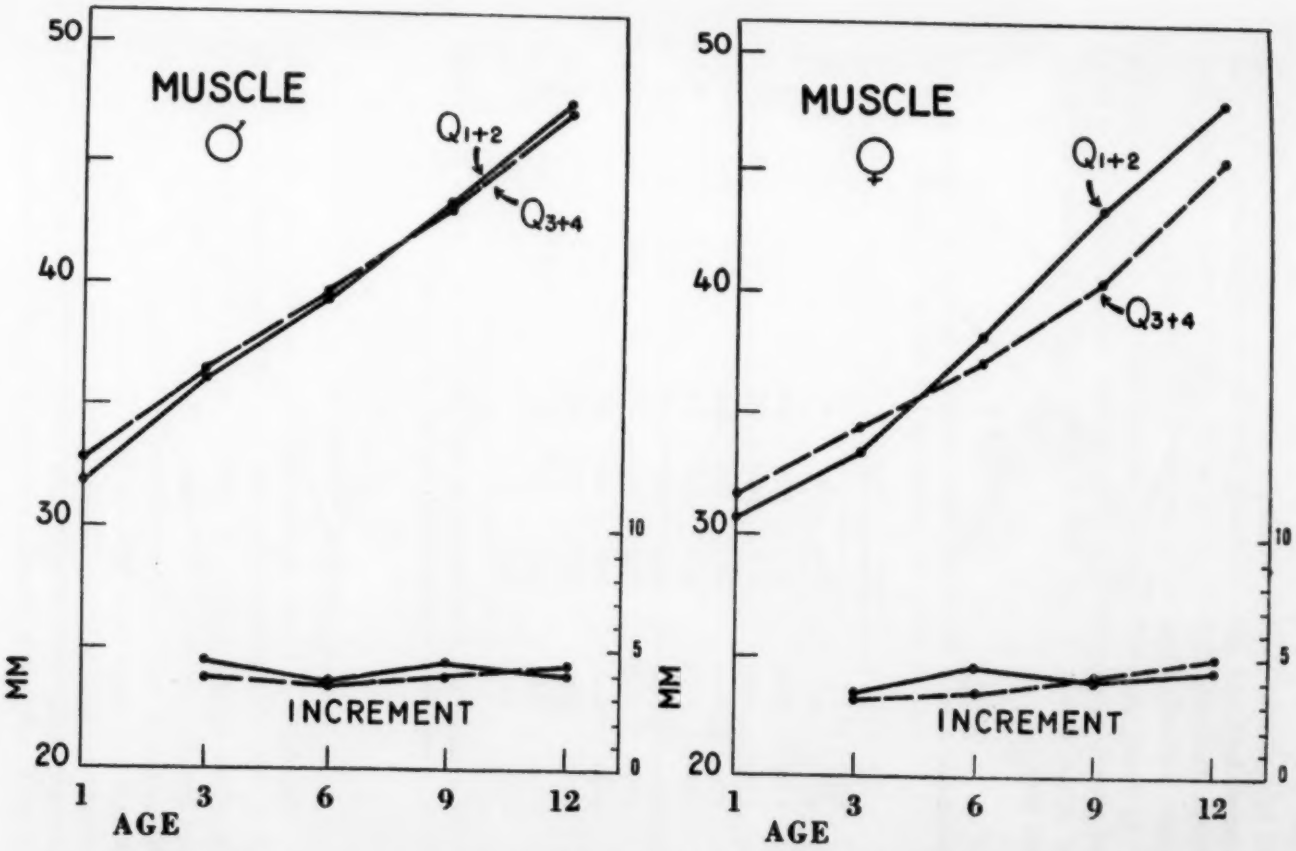

FIG. 5. Comparative transverse muscle breadths of fatter and leaner infants. There is a suggestion that late in the first year the leaner infants are endowed with greater musculature. This attains statistical significance only in the 9 month old girls.

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and by 9 months there is crossing over in both sexes so that the initially thinnest boys and girls eventually have the broader muscles. The two groups, markedly different early in life, regress toward the mean, and become virtually identical by the end of the first year.

It would seem therefore that subcutaneous fat relates to length, size and growth progress early in postnatal life, but the advantage of being fat at one month, if any, fails to carry through the remainder of the first year.

TABLE 3

Comparison of mean length and muscle percentiles for initially thinner (Q_1) and initially fatter (Q_4) infants at 1, 3, 6, 9 and 12 months

AGE	SEX	CROWN-HEEL PERCENTILES			MUSCLE PERCENTILES		
		Q_1	Q_4	t [1]	Q_1	Q_4	t [1]
1 mo.	Boys	37.1	68.8	4.6	36.7	51.0	2.2
1 mo.	Girls	31.0	62.4	4.2	32.4	56.3	3.0
3 mo.	Boys	41.1	62.0	2.9	51.8	54.5	0.4
3 mo.	Girls	34.8	54.5	2.4	39.4	47.8	1.0
6 mo.	Boys	52.5	58.6	1.1	49.4	48.2	0.1
6 mo.	Girls	36.6	50.5	1.6	44.9	57.8	1.5
9 mo.	Boys	56.5	54.3	0.3	53.7	43.8	1.0
9 mo.	Girls	39.1	47.8	1.1	47.3	42.1	0.6
12 mo.	Boys	55.2	53.0	0.3	51.7	45.3	0.8
12 mo.	Girls	40.1	47.8	0.9	45.3	43.3	0.2

[1] For values for N represented in this table, the .05, .02 and .01 confidence limits correspond to t values of 2.1, 2.5 and 2.8 respectively.

DISCUSSION

The findings in the present study indicate that, with the exception of the first month of prenatal life, there is little demonstrable relationship between the amount of subcutaneous fat on the leg and the size and growth progress of the infant. Though there are large individual differences in relative fatness during the first year, and the more obese infants have more than twice the fat thickness of the leanest, the fatter infants are not uniformly longer or more robust and the leaner infants are not shorter or of more delicate growth. If body size (as apart from weight) and growth progress are used as operational measures of nutri-

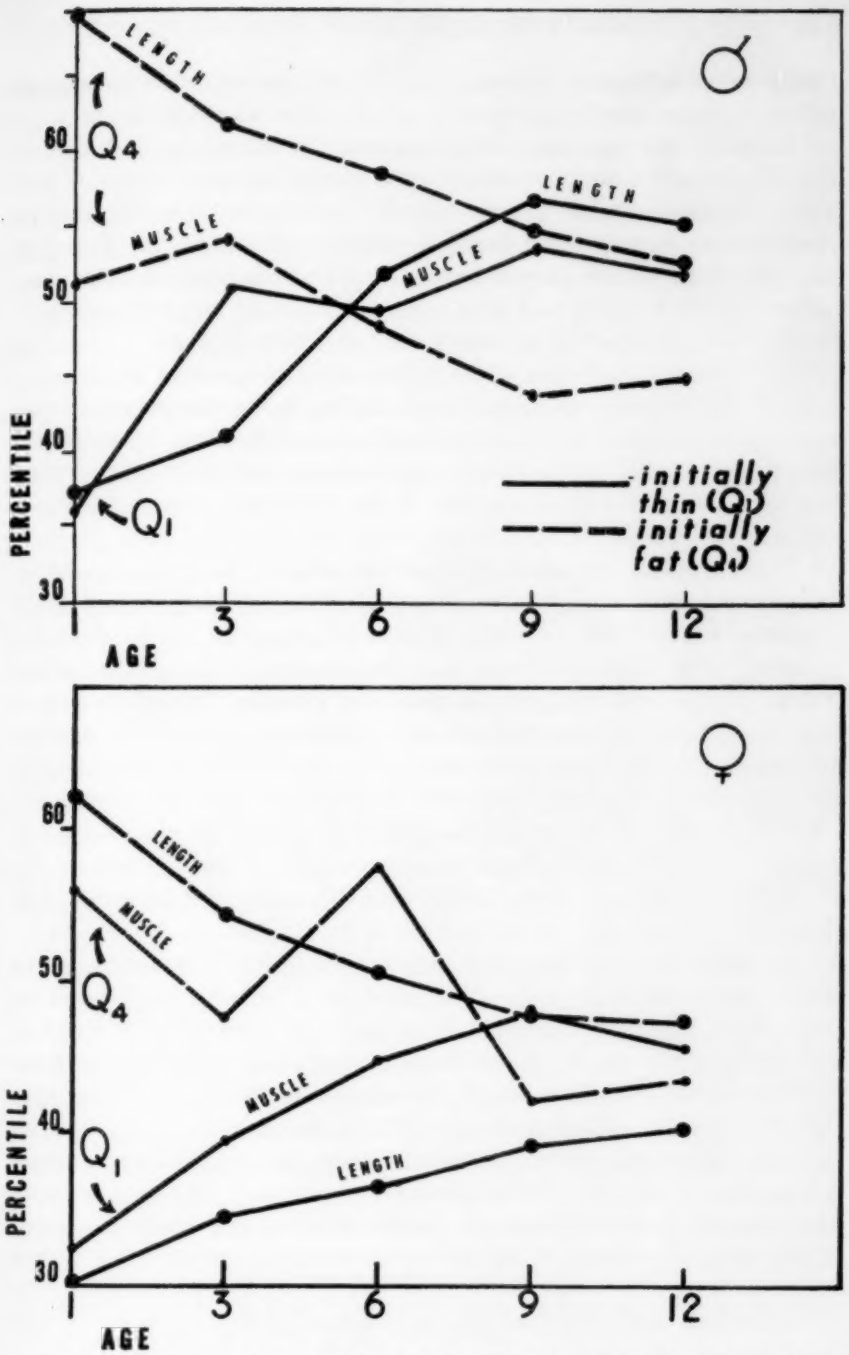

FIG. 6. Longitudinal comparison of two groups of infants, those in the first quartile (Q_1) and those in the 4th quartile of the fat distribution at one month (Q_4). The initially fattest infants are initially longer and broader-muscled. But the two groups converge. The differences are not statistically significant by the middle of the first year, and there is some evidence that the initially leaner infants develop more muscle.

tional status in healthy infants, then the amount of subcutaneous fat proves to be an uninformative index of the state of nutrition.

Moreover, the appreciably larger size of the fatter boys and girls at one month need not be attributed to a specific dynamic action of fat. Rather, analysis of the growth records of these fatter young infants show them to have been advanced, developmentally, at birth. The boys and girls in the fourth quartile for fat at one month weighed much more at birth ($3.77 \pm .07$ kg and $3.62 \pm .08$ kg) than did the boys and girls in the first fat quartile at one month (birth weight $3.17 \pm .08$ and $2.92 \pm .07$ kg respectively). In other words the apparent relationship between fatness and size at one month, is due to the persistence at that early age of differences in size and fat content at birth. But despite this "head start" the initially fatter infants do not maintain their size superiority, and by the middle of the first year, group differences virtually disappear.

There remains, of course, the problem of why the subcutaneous fat behaves as it does during early infancy, and this problem includes both the rapid accumulation of fat at a time when energy requirements for growth are at their maximum, and the seeming failure of the stored fat to contribute to the general motion of growth. Though it is true that the infantile accumulation of fat represents a temporal continuation of a trend started during late uterine life, reiterating this observation provides no further insight into the mechanisms involved. Similarly, the truism that fat represents the difference between energy input and energy output does not explain how appetite and growth are synchronized to facilitate the rapid accumulation and deposition of fat during early infancy.

It should be noted that milk, which even in these days remains the major source of calories for the infant, is in effect a high-fat food. Depending on breed differences, cow's milk provides up to 60% of its calories in the form of fat, while human milk—slightly lower in fat—provides up to 50% of the available calories in this form.[2] Since high fat diets providing approximately 60% of the calories in the form of fat are capable of inducing massive obesity in experimental animals (Mickelsen *et al.*, '55) the similarity between milk and such high-fat diets should be observed. And further, there is the possibly relevant fact that in our material, the age at which infants often begin to lose

[2] Calculated from table 1 and page 20 in Bowes and Church ('51).

fat is the age at which milk begins to play a decreasing role as the major source of calories.

Again, there may be a hormonal explanation for the fat gain in early infancy. Without going into the question of a "pyknophilic" hormone, or such a secretion as "adipokinin I or adipokinin II" (*cf.* Weil *et al.*, '47) there is at least one parallel where rapid fat addition has an hormonal basis. This is during adolescence in the female, where subcutaneous fat is greatly increased (Reynolds '50). Here, as in the replacement therapy of the female with ovarian agenesis, feminizing hormones do serve to direct the mobilization and deposition of fat. It may well be that hormones like cortisone (which promotes fat deposition) are both responsible for the rapid fat accumulation during infancy, and for individual differences in the amount of fat added during the first few months of life.[3]

There is no question that the amount of fat does relate to size and growth progress and therefore to "nutritional status" during childhood. Again in the adult, fat and health are related, though now fat becomes negatively related to longevity. Seemingly it is in transitional periods that fat appears to be a less useful measure of nutrition partly because at such times the implications of a given amount of fat depend upon the level of maturity attained. Ten millimeters of trochanteric fat may be indicative of obesity (in a late maturing 12 year old girl); alternatively, it may represent leanness (in a sexually mature girl of the same age). Similarly at one month of age, 10 mm of leg fat is meagre for developmentally advanced babies and generous for physiologically younger infants.

The result obtained in the present study are not those we expected to find. Based on previous experience with children and adolescents, especially the "fat-pad" group reported by Fry ('53) and Peckos ('53) it seemed logical that fatter babies would be appreciably larger, distinctly more robust and developmentally well ahead. But this is not the case, in normal healthy infants. In such infants, suffering from no feeding disturbance or avoidable vitamin lack, the amount of fat is scarcely related to size and growth progress. Under these circumstances

[3] The possibility of a neural mechanism affecting the differential deposition of fat on the lower limbs during infancy should be considered. Unilateral motor nerve paralysis does cause unilaterally increased fat deposition in paralytic children (Garn and Silverman, '55), but the inference that increasing motor nerve activity causes loss of leg fat is still premature.

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and within the restriction noted, it seems apt to repeat Batkin's ('15, p. 122) comment made 40 years ago, "We have no right yet to equate the thickness of the fat blanket with the state of nutrition: it is dubious whether we will have at some future time."

SUMMARY

1. The relationship between the thickness of the subcutaneous fat on the left lower leg, and size and growth progress in infancy was investigated in over 300 clinically healthy, presumably full-term infants at 1, 3, 6, 9 and 12 months of age.

2. As previously reported, subcutaneous fat increased rapidly in all infants from 1 to 6 months, doubling in median thickness. Thereafter, the tendency for some infants to gain fat while others were losing fat led to the appearance of stability as reflected by the "norms."

3. Comparing lean and fat infants, the latter were significantly longer at one month, but not thereafter. The same general trend was observed in tibial shaft length (extent of calcification along the diaphysis), whereas for muscle breadth the two groups did not show any consistent difference.

4. The initially leanest and intially fattest infants were markedly different at one month, but tended to converge and become indistinguishable thereafter.

5. The early and transient size superiority of the fatter infants at one month was shown to be a holdover from their superior size and developmental advancement at birth.

6. There was no evidence that the fatter infants were consistently more robust or faster growing, thereby questioning the use of subcutaneous fat as a measure of nutritional status in healthy infants during the first year of life.

7. Attention was drawn to the rapid accumulation of subcutaneous fat during the first part of the first year and the lack of satisfactory explanations for this phenomenon. The possible influences of high fat diet (which milk is) and of hormones directing the deposition of subsurface fat were considered.

8. In view of these findings, it was questioned whether—unlike childhood where fat and growth progress are related—the amount of subcutaneous fat can be used as a measure of nutritive status in otherwise healthy infants.

ACKNOWLEDGMENTS

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COMMENTS

Werner Kornfeld (New York Medical College, New York) made the following comment:

Nutritional anthropometry in children cannot be separated from a more general appraisal of body build and physical development. Different methods have to be applied in mass surveys, in research projects, and in pediatric practice. For different age groups different measurements have to be selected as minimum requirements. Out of a larger group of measurements which were used in studies made on children in New Jersey (Oesterreichische Zeitschrift für Kinderheilkunde, 10:71, 1954) the following measurements were selected as minimum requirements for the characterization of body build and physical development in infants: body length, stem length, body weight, head circumference, and chest circumference at two different levels (supramamillary and xiphoid). The advantage of taking these two measurements of chest circumference has been explained in an earlier publication (Journal of Pediatrics 42:715, 1953). A method of graphic illustration of the main features of body build based upon these measurements ("2/3 base line method") has been described (Journal of the Newark Beth Israel Hospital, Newark, N.J. 6:199, 1955).

In older children, after the fifth year of life, head circumference may be omitted. To characterize further the relation between longitudinal growth and circumferential growth in older children, inclusion of wrist circumference and of hand length are suggested.

For the special purpose of studying the soft tissue distribution the following measurements were used: circumference of forearm, arm and calf; skinfold measurements on the chest (infraclavicular), on the abdomen (lateral from the umbilicus), and on the back (medial from the inner margin of the scapula). Another measurement, characterizing the soft tissue masses in the cheeks, was obtained in the following manner: anthropometric calipers were used to measure the bizygomatic diameter (over symmetrical points of the most prominent part of the zygomatic

arch), first without any pressure, avoiding any indentation of the skin, and then with moderate pressure towards the underlying bone structure. The difference between these two measurements gave a measure of the compressible or displaceable amount of subcutaneous masses in this region. It can be shown that this measurement follows rules in the normal development as well as in pathologic deviations which are different from those which govern the behavior of the skinfold measurements in the three regions mentioned above. Mean values obtained in different age groups for skinfolds and for soft tissue masses on the cheeks, and graphs demonstrating characteristics of soft tissue distributions in different age groups, are being prepared for publication in the near future.

R. F. A. Dean (Medical Research Council, Kampala, Uganda) referred to the studies of growth and development that are in progress in European and African countries, under the auspices of the International Children's Center in Paris, with support from the World Health Organization. The studies, which include somatotyping and anthropological measurements by the photographic method, all use the same techniques, so that the information obtained at the various centers may be truly comparable.

In Uganda, it has been found that the use of standards obtained from child populations in the U. S. A. and in European countries cannot be used on the African community without many reservations. There appears to be a different pattern of development in the African child: his height/weight ratio does not change in the same way as that of the U. S. child, and his bone age (as shown by x-ray examination of the hand) may, at early ages, be in advance, and not retarded as might be expected. The advance is paralleled by a precocity of psycho-motor development, and may be related to the early precise use of the hand and fingers.

Although there may be a dominant genetic control of the pattern of growth, as well as genetic control of final stature, there is undoubtedly some variation imposed by the plane of nutrition. The exact importance of nutrition is uncertain: it is being studied in Kampala, where a serious degree of under-nutrition may be present in a high proportion of children. Similar work would be difficult in the U. S., but there it should be possible to study different racial groups, to determine whether or not the development of the children in these groups follows the usual U. S. pattern.

ALLOMETRIC GROWTH OF BODY COMPOSITION IN MAN AND OTHER MAMMALS

BY EDWARD E. HUNT, JR. AND EUGENE GILES

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AN important development in the recent study of human biology has been the measurement of body composition in the living, and the literature in this field is now voluminous. Enough is known of the composition of young American White men to permit the tentative definition of a "reference man" of average weight for stature, and aged 25 years (Keys and Brožek, '53). The composition of women and children, however, is less fully known, and the present paper is a preliminary attempt to work out developmental trends in a few body constituents in both sexes.

The basic techniques of measurement in the study of body composition *in vivo* include the determination of density ("densitometry"), and the estimation of body water content by the dilution of foreign substances in the blood and other fluid compartments ("hydrometry"; *cf.* Brožek, '54). When both water content and density are measured on one occasion, the fat content of the organism can be determined with appropriate allowance for varying hydration, which may be an appreciable source of error in measuring fat from densitometry alone.

With reference to total body weight, the water content of man shows considerable individual variation. This variation is roughly the inverse of body fat content because adipose tissue contains far less water than does the remainder of the organism. But even with reference to the fat-free weight, hydration shows some variation in man (Bass, '54). This variation makes the determination of the individual fat-free weight uncertain from the weight of water alone, but such errors are less critical when group trends are calculated on reasonably normal subjects. Finally, the errors of measurement themselves are fairly large in at least some of the current hydrometric techniques.

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Despite these difficulties with the hydrometric method, it is a logical starting point in extending the measurement of body composition in the living from men to women and children. The findings from this initial attempt can later be compared to those based on other known methods in this field. This array of analytical procedures might include such diverse measures of fat as the dilution of fat-soluble indicators, densitometry, and skinfold thicknesses. Determinations of fat, muscle and bone are possible from radiographs, and perhaps significant relationships between these tissues and metabolism can be established.

Underlying any secure methodology in the study of body composition is the chemical analysis of carcasses, whether growth studies are contemplated, or work on mature individuals. Some of the trends in the chemical growth of the animal body have been known since the pioneering work of von Bezold (1857), but much of the precise knowledge in this field is recent. For a few species of mammals, carcass analyses are numerous from the fetal period to maturity (Needham, '42). For man, however, although many analyses have been published of fetuses and stillborn neonates, few such studies are available on older individuals. Not much further progress on man can be expected unless this lack of data is overcome, or unless close analogies are demonstrated between lower mammals and the human species. Still another difficulty with human data is that the analyses have been based mainly on individuals who have died in a poor state of health, while the animal studies usually have been done on more normal specimens.

Despite the inherent limitations in the present study, we shall attempt to calculate normal growth trends of fat, water, and the aggregate of solids in the fat-free body (including minerals). Total non-fat solids plus water equal the fat-free body weight. "Extractable" fat is then the difference between total body weight and fat-free weight.

In his studies of the growth of the fat-free mammalian body, Moulton ('23) enunciated the concept of "chemical maturity." This phrase refers to the attainment of mature concentrations of water, protein and ash in the fat-free mass of the young animal. But as Spray and Widdowson ('50) have demonstrated, not all chemical constituents of the fat-free body attain their mature concentrations at the same chronological age. A more limited concept, to be used here, is the attainment of the young adult concentration of water in the juvenile fat-free body. One might speak of this stage as "aqueous maturity," or as we have done, "mature hydration."

In boys and young men, mature hydration can be defined from the composition of the "reference man" of Keys and Brožek ('53). In this standard, 70.9% of the fat-free body weight is water. The importance of discovering the minimum age of mature hydration in the male is that it defines a lower limit above which the prediction of other body constituents from water can be done by equations now available for young men. A parallel argument would apply to girls if a "reference woman" could be defined.

It is equally desirable to estimate the developmental changes in the water content of the fat-free body in children younger than the age of mature hydration. Much of the present paper is concerned with this problem, and where trends cannot be measured directly in man, comparable data are utilized from lower mammals. These estimations are based on the principle of relative growth or *allometry*.

THE ALLOMETRIC METHOD

The fundamental principles of allometry are to be found particularly in the treatise of Huxley ('32), who extensively developed and used the concept. Allometry is a mathematical technique for characterizing the relationships of size or concentration of two parts or constituents of the animal body (*cf.* Smith, '54, p. 120). In some instances the technique is applied to the percentage rate of increase of an organ or chemical constituent as compared to that of one of its parts. In other instances measurements of two distinct parts or constituents of the body are utilized. The symbols x and y are applied to the measurements, and in practically all allometric studies, the relationship between x and y is expressed by the following equivalent equations:

$$\text{Exponential } y = bx^k$$

$$\text{Logarithmic } \log y = \log b + k \log x.$$

The logarithmic form of the equation describes a straight line with slope k. Although time does not formally enter the allometric calculations, it is often convenient to think of k as a ratio between the percentage increases of x and y per unit of time. When $k = 1$, the increases of the two measurements maintain a proportional constancy, such that the constant $b = \frac{y}{x}$.

When $k > 1$, the percentage increase of y is more rapid than that

of x, while when $k < 1$, the reverse is true. Where $k \neq 1$, the b coefficient is simply a suitable multiplier without any obvious biological significance.

Simpson ('53) has characterized the abundant literature on allometry. In paleontological studies, allometric equations may describe alterations of size and shape in an evolutionary lineage of organisms (lineage allomorphosis). Comparisons are also possible, without regard for time, among contemporaneous members of separate but related genera or species of animals such as the living anthropoid apes (Giles, '56). Within one species, one set of equations may fit the growth of immature individuals within empirically determined limits of size (heterauxesis), and another set may apply to the differences between small and large adults (individual allomorphosis).

Huxley ('32) showed that stable allometric relationships between the sizes of most body parts are often found in animal growth after the end of the embryonic period, when the major organs and tissues have become recognizable. The compilations of Huxley, and also of Needham ('42) indicate that it is generally more risky to extrapolate fetal allometric curves back into the embryonic period than forward into later growth.

The first applications of allometry to human growth were mainly based on fetal carcass analyses. Iob and Swanson ('38) calculated k values for a number of chemical constituents. Hamilton ('36) worked out a k coefficient for water and total dry substance (including fat) in the human fetus, and extrapolated his curve to the adult stage in order to estimate the water content of mature and aging human individuals. Needham ('42) published a large table in which water and dry substance were translated into allometric equations for many animal species, including man. His k coefficient for man applies from the fetal period to an adult weight of 66,000 g.

By combining data on fetal carcasses, living children and young adults, Forbes ('52a, '52b) found that the potassium and sodium concentrations of body fluids maintain allometric relationships with total body weight in older fetuses, children, and young adults. Forbes himself, and later Cheek ('54), found further allometric equations relating the chloride concentrations of body fluids and total body weight. The values of k for sodium and chloride are similar enough to suggest that an allometric "desalting" of the body occurs during growth. This loss, in turn, seems to indicate that the percentage of extracellular fluid in the human body correspondingly decreases.

Forbes ('52a) has also computed two allometric equations relating body water and total body weight. One applies to younger fetuses up to a weight of 373 g, and the other extends from 490 g to the mature weight of 84,800 g. In this instance, however, his results suffer from the fact that the weight of the body is largely water, so that one variable in both equations is incorporated into the other. When the incorporated variable is small, as potassium versus body weight, the conclusions are not greatly affected. But if the variable is large, as is true for water, the allometric method produces an artificially high correlation between log x and log y. The overlap of the two variables will also tend to obscure other important allometric relationships by necessarily inducing the k coefficient to approximate unity, as pointed out by Reeve and Murray ('42).

In the present study, this difficulty is met by separating water from total fat-free solids, and using them as the two variables in the allometric equations. This separation is intended to result in a biologically more meaningful formulation of their interrelationships.

ALLOMETRY OF WATER AND SOLIDS IN HUMAN FETUS

Although recent compilations of human fetal carcass analyses (such as Kelly *et al.*, '51) contain considerable numbers of specimens, many of these fetuses had to be eliminated for various reasons from the present study, and additional specimens were included from Widdowson and Spray ('51). The fetuses accepted for study here were all weighed intact and then dried in a low temperature oven. The difference between the original wet weight of the specimen and its dry weight equals total body water (in grams). The dry specimen must then have undergone fat extraction, so that fat-free solids in grams represent dry weight minus the weight of fat removed.

The sources of data included 15 male and 6 female fetuses from Fehling (1877), three males and three females from Camerer ('00a, '00b, '02), one male each from Brubacher (1890) and Sommerfeld ('00), and 11 males and 6 females from Widdowson and Spray ('51). Thirteen fetuses of unstated sex were used from Iob and Swanson ('34), and one from Langstein and Edelstein ('17).

The estimated menstrual age range of the specimens (chiefly from Kelly *et al.*, '51) was from 3.6 lunar months to term. Male body weights ranged from 36.5 to 4,375 g, female weights from 156.8 to 3,767 g, and for fetuses of unstated sex the range was from 59.4 to 2,915 g.

The allometric calculations were performed on an individual basis, by the method of least squares. Separate equations are presented for males, specimens of unstated sex, females, and for the total series. As shown in table 1, these equations are based on highly correlated logarithmic variables, and are therefore indicative of true allometric relationships.

TABLE 1

Allometry of water and fat-free solids in human fetuses

GROUP	N	EQUATION	σ_{est}	σ_k	$r_{\log S \cdot \log H_2O}$
(1) Males	30	$\log S = 1.251 \log H_2O - 1.509$	0.399	0.025	.9943
(2) Sex unstated	14	$\log S = 1.254 \log H_2O - 1.506$	0.159	0.029	.9969
(3) Females	15	$\log S = 1.275 \log H_2O - 1.581$	0.070	0.013	.9993
(4) Total series	59	$\log S = 1.255 \log H_2O - 1.518$	0.436	0.016	.9958

t test of significance of difference between male and female k coefficients:

$$t = 0.53 \quad p > .05.$$

Finney ('38) devised a statistical test, in the form of a critical ratio, which is a measure of the significance of the observed deviation of k from a value of $k = 1$. All of the fetal values of k shown in table 1 are very significantly greater than unity; p in all cases is less than 1 in 1,000 except in (2), where $p < .01$.

The males and specimens of unstated sex show practically identical equations: the females show higher absolute values of k and b. The agreement of the first two equations suggested that the female result might be a sampling deviation, and a test of significance was applied to the k ratios of the males and females (Simpson and Roe, '39). The difference was not significant, and consequently the equation for the total series is considered to be applicable to fetuses of either sex.

REFERENCE STANDARDS

Data at hand for the formulation of neonatal reference standards are not abundant. Widdowson and Spray ('51) analyzed three male specimens ranging in weight from 3,105 g to 4,375 g, and three females ranging from 3,050 to 3,767 g. These authors defined a single reference standard for both sexes, weighing 3,500 g, and containing 14% fat, 71.5% water, and 14.5% solids.

Our interpretation of these same raw data is that the male and

female reference neonates should be alike in composition, but the female should be lighter in total body weight.

In arriving at mean reference weights for newborn American boys and girls, a grand mean for each sex was obtained from the separate means of 4 recent growth studies. The sources used were Vickers and Stuart ('43) for a group of Boston children, Bayley and Davis ('35) for a sample from Berkeley, California, Sontag and Reynolds ('45) for a series from central Ohio, and Boyd ('41) for a sample from Minnesota. The reference male neonatal weight is 3,550 g, and that of the female is 3,350. Both contain 14% of fat as recommended by Widdowson and Spray ('51).

The allometric equation for the total fetal series indicates that a fat-free body weighing 3,053 g should contain 2,496 g of water (70.3% of total body weight), and 557 g of solids (15.7%). These are accordingly the concentrations of water and solids in the male reference neonate.

For the female neonate, with a fat-free body of 2,881 g, the water content should be 2,362 g (70.5% of total body weight), and solids 519 g (15.5%).

Compared to the standard of Widdowson and Spray, the water contents of these reference neonates are perhaps 1% too low, and raise the possibility that dehydration of the fetal body before analysis (especially in the smaller specimens) is a systematic source of error in the equations. Hamilton ('36) had similar suspicions regarding his own equation, based on some of the fetuses used here (those of Iob and Swanson, '34). The present computations do verify, however, that the two sexes are probably alike in their composition of fat, total solids and water at birth.

The next step was to define a "reference woman" of age 25 years to compare with the reference man. Such a definition is somewhat suspect because of a scarcity of suitable data on the body composition of women. One possible reference body weight would be the mean of 8,516 abundantly fed young U. S. Army women from World War II (Randall and Munro, '49) at 59.8 kg, but in deference to civilian female sensibilities we have used the slightly lighter 58 kg, which is closer to the female mean "standard weight" for age 25, according to the Medico-Actuarial Standards of 1912. This choice is also consistent with the weight of the reference man, which is 70.6 kg, and which was similarly chosen from the 1912 tables (Keys and Brožek, '53).

From measurements of specific gravity in the living, Skerlj, Brožek and Hunt ('53) estimated that the mean fat content of 23 young women

aged 18–30 years was 26.2% of body weight. Since the true mean standard weight of these women (relative to the Medico-Actuarial Standards) was 94.13%, the average young woman at the full standard weight is probably more adipose. A choice of 28% of fat for the reference woman seems more reasonable.

Since the two sexes are alike at birth in average composition, but the female is lighter in weight, it is of theoretical interest to construct the reference woman as though she, too, had essentially the same composition as the reference man, but with considerably more adipose tissue. Such a definition would make possible the use of existing adult male equations for body composition in the female as though she were a small, relatively adipose man. Somewhat analogous reasoning underlies the use of the same equations for both sexes in predicting total body fat from specific gravity or density.

In the computations which follow, the excess adiposity of the female will be interpreted as equivalent to the so-called "obesity tissue" gained or lost during moderate changes of weight in men (Keys, Anderson and Brožek, '55). As characterized by a combination of measurements of body density and body water, obesity tissue consists of 62% fat, 31% water, and 7% cell solids. The residual composition of the reference woman is that of the reference man: 14% fat, 61% water, and 25% non-fat solids. (Non-fat solids consist of 19% cell solids and 6% bone mineral.)

As previously defined, the total body weight of the reference woman is the sum of the obesity tissue and residual composition, or 58,000 g. Twenty-eight per cent of this aggregate is fat, or 16,240 g.

Let $Q = 1\%$ of the added obesity tissue

and $C = 1\%$ of the residual composition.

We solve the following two simultaneous equations to find Q and C:

$$\text{Weight of reference woman} = 58{,}000\,\text{g} = 100Q + 100C$$

$$\text{Fat of reference woman} = 16{,}240\,\text{g} = 62Q + 14C.$$

These equations yield $Q = 169.17$ g, and $C = 410.83$ g.

We then construct the reference woman by applying the appropriate multipliers:

CONSTITUENT	OBESITY TISSUE		RESIDUAL COMPOSITION		REFERENCE TOTAL (GRAMS)
Fat	$62Q$	+	$14C$	=	16,240
Water	$31Q$	+	$61C$	=	30,305
Solids	$7Q$	+	$25C$	=	11,455

In percentages of total body weight, the reference woman contains 28% fat, 19.7% non-fat solids, and 52.3% water. The agreement of this water content with averages in the literature for young women of representative average weights seems to support the preceding formulation: *i.e.*, Forbes ('52a) gives 51.9% as a mean for 11 women under 35 years of age. Edelman *et al.* ('52) give 51.5% for 19 women with a mean age of 23.8 years.

On a fat-free basis, the reference woman contains slightly more water than the reference man: *i.e.*, 72.6% as opposed to his 70.9%. These two values are used to define the mature hydration of male and female children in the calculations later in this paper.

FETAL ALLOMETRY OF WATER AND SOLIDS IN LOWER MAMMALS

In man, the data of Needham ('42), Hamilton ('36) and Forbes ('52a) indicate that total body water maintains an allometric relationship with total body weight or with total dry substance from the fetal period to the adult. But where water is related to *fat-free* solids, it is well to attempt new calculations. In a few lower mammals, for example, carcass analyses are plentiful enough so that separate allometric equations can be computed for the fetal period and for postnatal growth. This separation is not only a test of discontinuities at birth but may also suggest what kind of postnatal equation for solids and water might be applied to man, for whom no suitable carcass analyses are available.

Unfortunately, most of the fetal allometric calculations of Needham ('42) are based on studies where the specimens were dehydrated to determine dry weight, but were not subjected to fat extraction. A fetal equation so calculated will not be seriously in error if it is based on fairly immature fetuses, which in all mammals are practically fat-free, or on the whole fetal period in species where the newborn is virtually fat-free.

One such study was carried out in the pig. Wilkerson and Gortner ('32) performed carcass analyses of 1,552 embryonic and fetal pigs, ranging in weight in various age groups from 0.3 to 725 g. We consider these "solids" to be equivalent to our "fat-free solids." Needham ('42) calculated an allometric k coefficient, predicting solids from water for this series, and its value was 1.07.

In the rat, which contains only about 1% of fat at birth, Hamilton and Dewar ('38) performed analyses of 585 fetuses, ranging from the

14th day of gestation to term at 21 days. Water and dry substance in this instance showed an excellent allometric relationship, with the correlation between the logarithms of the two variables being +.9999. Predicting water from dry substance, these authors obtained a k of 0.875. The reciprocal of this coefficient, which is very nearly correct when the correlation is so high, is the prediction of solids from water. By this transformation, $k = 1.14$.

Our human fetal k coefficients were considerably higher. Relative to man's prenatal accumulation of body water, his "solidification" is striking. This trend is doubtless related to the consistently low water content and abundance of bone in the human fat-free body. This abundance of bone, in turn, probably accounts for the comparatively high concentrations of calcium, phosphorus, and sodium in the human fat-free body (Spray and Widdowson, '50).

POSTNATAL GROWTH OF BODY CONSTITUENTS

For comparison with the fetal coefficients for the rat and pig, and in order to explore more fully the postnatal allometry of water and solids in the fat-free mammalian body, data were taken from a recent synthesis of postnatal growth trends by Spray and Widdowson ('50). The carcass analyses most fully described in their paper are for the rat (black and white Hooded strain), pig (hybrids of Wessex and Large White in varying genetic proportions), and the rabbit and cat.

For two of these species (rat and rabbit), the series were large enough to permit separate studies of males and females. In both species, the sexes at birth were similar in mean fat, water and total solids, but the females were slightly lighter in weight. The human reference standards described previously were constructed in a similar manner.

First to be considered in the postnatal growth of these lower mammals is the fat content of the body. In all of the species studied, fat rapidly accumulates during the suckling period. After the end of weaning, the rat shows a temporary slackening in this rate of increase, but the other species show a true loss of fat relative to total body weight. This relative loss is reversed just before or during adolescence, and a relative accumulation sets in. The rat is peculiar in losing fat late in adolescence: the other species continue to show some increases. In the rat and rabbit, where the two sexes were studied separately, the female body does not contain more fat than that of the male until after puberty.

By comparison with most other mammals, man is unusually adipose at birth, but he, too, fattens considerably during the suckling period. Stuart and Sobel ('46) have measured the thickness of the medial and lateral layers of skin and subcutaneous tissue in the calf of the leg from radiographs of children followed serially for a number of years. These thicknesses attain an early maximum at 9 months of age which seems to correspond to the maxima of total body fat seen at weaning in the pig, rabbit and cat. After 9 months of age, these adipose layers become thinner at a decreasing rate until after the age of three years, remain about constant from 5½ to 11, and thicken again thereafter.

It is risky, however, to estimate the total body fat content of children from such measurements—particularly in the calf of the leg. As Reynolds ('52) has demonstrated, the subcutaneous layer undergoes considerable changes in distribution prior to adolescence. In general, these changes are in the direction of a considerable relative loss of thickness on the distal segments of the limbs, smaller losses on the proximal segments, and accumulation on the trunk. This redistribution prevents the reconstruction of a clear picture of trends in total body fat from any localized radiographic measurements of the subcutaneous layer in man.

In addition, if the subcutaneous layer maintains a constant thickness in a limb which is growing in girth, the percentage of adipose tissue in this region must be decreasing.

In a study now being prepared for publication, Mr. Paul T. Baker, Mrs. Tulika Sen, and one of us (Hunt) have been calculating idealized areas of cross-section of the brachium from measurements of radiographic shadows of children and young adults. The tissues measured have included marrow cavity, compact bone, muscle and adipose tissue at a point midway from acromion to olecranon. The age range of the individuals studied was from 6 years to young adults.

In boys, the precentage of adipose tissue at mid-brachium decreases constantly during this age span. In girls, the decrease ends at about 12 years, and in adolescence a slight increase occurs. The steady decline of adiposity in the male arm is unusual compared to total body fat in other known mammals. The trend in girls, however, resembles those of the pig and rabbit, whose total body fat shows relative decreases before adolescence, and slight increases thereafter. There is no certainty however, that the adipose trends in the human brachium really correspond with those of total body fat.

As early as one year of age, girls tend to show more thickness of the subcutaneous layers of the leg than do boys (Stuart and Sobel, '46). The female rat and rabbit, however, do not show a sex difference in total body fat until puberty.

In turning from fat to water and solids, the data of Spray and Widdowson ('50) portray the postnatal relative decrease of water in the fat-free body of several lower mammals. In the rat and rabbit, both species reach puberty at about the middle of their postnatal span of growth, and mature hydration soon afterward. We have calculated that at mature hydration, the rat is at about 75% of its adult weight, and the rabbit at 85%. The pig has a very early puberty, but like the other species, reaches mature hydration about halfway through its postnatal growth span. Its weight at mature hydration is about 75% of the adult value. The cat, however, is unusual in attaining mature hydration not long after weaning, and puberty near the end of its growth. At mature hydration, this animal is at only 60% of its adult weight.

If man shows any resemblance to these species, we should expect him to attain mature hydration at the latest toward the middle of his postnatal time span of growth, and at a weight of between 60 and 85% of the adult value.

There remains the question of whether water and solids maintain strict allometry in their postnatal growth in lower mammals, at a time when fat undergoes quite different rates of accumulation or relative loss from one species to another. To examine this question, a series of allometric equations was computed by the method of least squares, using data on water and solids from the tables and charts of Spray and Widdowson ('50). Only ages below the probable time of mature hydration were included.

Since means of several age samples were used for each species instead of individual specimens, the correlations between log solids and log water are higher than they would be otherwise, and individual standard errors of estimate of solids from water cannot properly be given. The weights of both constituents are in grams.

Table 2 shows that all species exhibit a postnatal allometry of water and solids up to the age of mature hydration, despite their different relative accumulations and losses of fat. These findings are highly suggestive of a comparable allometric pattern during human postnatal growth.

In the rat and rabbit, where separate curves were calculated for

males and females, the females showed higher absolute values of the k and b coefficients. Especially in the rat, the female reaches mature hydration younger than the male. A hint of such a sex difference was also found in the human fetal equations for males and females, but was dismissed from further consideration because the divergence was far from approaching statistical significance.

In the pig and rat, where comparisons are possible between prenatal

TABLE 2

Postnatal allometry of water and fat-free solids to time of mature hydration in lower mammals

	SPECIES	SEX	N	AGE RANGE (DAYS)	EQUATION	$r_{\log S \cdot \log H_2O}$
(5)	Rat	Male	76	0–120	$\log S = 1.24 \log H_2O - 1.00$	.9994
(6)	Rat	Female	73	0– 90	$\log S = 1.25 \log H_2O - 0.96$	.9998
(7)	Rabbit	Male	22	0–250	$\log S = 1.14 \log H_2O - 0.94$	.9933
(8)	Rabbit	Female	21	0–250	$\log S = 1.18 \log H_2O - 1.05$	.9967
(9)	Cat	Both	18	0–126	$\log S = 1.18 \log H_2O - 1.02$	.9990
(10)	Pig	Both	37	0–251	$\log S = 1.10 \log H_2O - 1.03$	.9995

and postnatal values of k, the postnatal coefficients are higher. The increase in the pig is from 1.07 to 1.10, and in the rat, from 1.14 to 1.24.

After birth in these species, then, the fat-free body "solidifies" more rapidly than prenatally, relative to the accumulation of water. Especially in the rat, the use of a fetal equation for predicting solids and fat in older juvenile animals would result in systematic underestimation of solids, and therefore a corresponding overestimation of fat. It would also yield too late an age of mature hydration.

If man, too, "solidifies" more rapidly after birth than prenatally, the same errors should result from using the fetal human equation for predicting solids, fat, and the time of mature hydration in children. But this fetal equation is very useful in indicating a likely *maximum* age of mature hydration, beyond which adult hydrometric equations can be used with considerable confidence.

Furthermore, if this maximum age agrees well with the established ages of mature hydration in some of the lower forms, this finding might indicate that at the most, the postnatal acceleration of "solidification" is small in man, as in the pig, rather than large as in the rat. Finally,

the smaller the postnatal acceleration of k in man, the more accurately the fetal equation will delineate the postnatal trends of fat and solids in children.

MATURE HYDRATION IN MAN

In calculating the body size and probable timing of mature hydration during human growth, the equation for the total human fetal series was used. The ratios of water and solids at which mature hydration is reached in boys and girls were arrived at by successive approximations.

Mature hydration in boys, where water is 70.9% of the fat-free body weight, is reached when the body contains 27,000 g of water, so that the fat-free weight is 38,067 g. In girls, mature hydration at 72.6% of water in the fat-free body is attained when water reaches 19,500 g, so that the fat-free weight is 26,845 g.

For boys, if we assume that this fat-free weight is 80% of total body weight, the intact individual then weighs 47.6 kg. If the corresponding fat-free weight of the female is 75% of total body weight, the intact body at the onset of mature hydration weighs 35.8 kg.

In males, body weight at the onset of mature hydration is then 67% of the weight of the reference man. The equivalent stage in girls is at 62% of the weight of the reference woman. In both sexes, these weights are in the lower portion of the range for lower mammals which was described previously (60–85%). This finding suggests that the postnatal allometric accumulation of solids in the human fat-free body proceeds at approximately the fetal rate or, at most, a slight acceleration occurs as in the pig.

In boys and girls, when the body weights at the onset of mature hydration are translated into age equivalents, using mean weights for age published by Sontag and Reynolds ('45), it is estimated that boys reach mature hydration at almost 14 years of age, and girls at about 10½ years.

These calculated ages of mature hydration in man occur at about the middle of the postnatal time span of growth, as in the pig, rat and rabbit. The precocity of the human female seems to be part of a pattern of rapid maturation which affects most of the body except for the eruption of the deciduous teeth (Meredith, '46).

WATER, SOLIDS AND FAT IN PREADOLESCENT CHILDREN

Friis-Hansen *et al.* ('51) have published deuterium oxide and antipyrine determinations of total body water for 20 children from neonates to the age of 10.8 years. These children were patients at Children's Hospital, Boston, so that some question may arise as to their "normality" of body composition. Despite this doubt, the more numerous male sample of 16 individuals has been used to calculate age trends of water, solids and fat, where each constituent is expressed as a percentage of total body weight. Water in each individual was the mean of the D_2O and antipyrine spaces. From this mean value, solids were calculated by the allometric equation for the total fetal series which was derived earlier.

Where age in years is represented by A, the least-squares regression of non-fat solids on age from birth to 10.8 years is expressed by the following equation:

$$(11) \qquad \%\ \text{Solids} = 0.43A + 16.16.$$

The initial, or neonatal value of solids in this equation, where $A = 0$, agrees fairly well with the reference neonatal male value of 15.7%. Through the preadolescent years, boys accumulate solids with great regularity. A less certain deduction is that this equation continues to apply during adolescence. If the precentage of solids in the reference man (25%) is substituted into this equation, we obtain a terminal age for progressive "solidification" of just under 21 years. Research on adolescents should determine whether solidification is regular from 10 to 21 years, or accelerates during the adolescent growth spurt and slows down afterwards.

The original data of Friis-Hansen *et al.* ('51) show that total body water rapidly declines relative to body weight up to the age of 9 months, and is far more stable in the later preadolescent years. The following equations express the age trends of water in boys:

$$(12) \qquad \text{(Birth to 9 mo old)}\ \%\ H_2O = 71.06 - 14.69A.$$

$$(13) \qquad \text{(1 year to 10.8 years)}\ \%\ H_2O = 59.52 - 0.42A.$$

The equations for water and solids for corresponding ages can easily be combined to produce equations expressing the hydration of the fat-free body as related to age.

$$(14) \quad \text{(Birth to 9 mo old)}\ H_2O(\%\ \text{fat-free body}) = \frac{7106 - 1469.1}{87.22 - 14.26A}.$$

At later ages, with the cancellation of practically equivalent terms in the denominator, we arrive at the simple expression:

(15) (1 year to 10.8 years) H_2O(% fat-free body) $= 78.6 - 0.6A$.

The equations for fat content of the total body are readily obtainable if the equations for water and solids are combined, and then subtracted from 100%. By this method, we obtain one equation for fat up to 9 months of age, and another extending from one to 10.8 years.

(16) (Birth to 9 mo old) % Fat $= 12.78 + 14.26A$.

(17) (1 year to 10.8 years) % Fat $= 24.32 - 0.01A$.

These equations show that the value for fat in the newborn is 1.2% lower than that of the reference male neonate, probably because lengths were average in the 8 young infant males studied, but weights were a little low relative to the standards in Sontag and Reynolds ('45). Nevertheless, in this group, the fat content of the body almost doubled in the first 9 months of postnatal life. Up to 10.8 years, fat is essentially stable, while water slowly declines and solids accumulate at inversely corresponding rates.

This stability of total body fat in boys runs counter to the relative loss of adipose tissue at mid-brachium as shown from radiographs. The discrepancy would be even more marked if mature hydration is attained at any age younger than the one predicted from the fetal allometry of water and solids in man.

Although the preceding equation for water as a percent of the total body weight in older preadolescent boys indicates a slight decrease, it is based on a sample of only 8 individuals. A constant water content from one to 10 years is almost equally plausible, but if mature hydration were reached during this interval, from that time onward the curve for solids would have the same slope as the curve for water. Correspondingly, fat would either remain constant, or else increase.

From these considerations, we conclude that the loss of fat in the brachium in boys from 6 years onward is produced by a *redistribution* of the subcutaneous layer rather than by a reduction in the total fat content of the organism.

This finding again emphasizes that radiographic shadows or skinfolds are very valuable *localized* indicators of adiposity in children, but it will probably be no simple matter to use them for the prediction of total body fat.

BODY COMPOSITION IN ADOLESCENCE

Since the ages of mature hydration were calculated from the fetal equation for children of both sexes, these estimates are apparently either correct, or else slightly overshoot the mark. Because these calculated ages are maxima, *hydrometric equations based on young adults can be used with confidence on adolescents.*

In boys, the regression equations on age of fat, solids and water suggest that adolescence involves a considerable transformation of body composition. The normative composition of a 10-year-old boy, as calculated from these equations, is about 24% fat, 55% water and 21% nonfat solids. The reference man is far less adipose and more "solid," with 14% fat, 61% water and 25% solids. The trends by which this transformation is achieved remain to be worked out in the future.

Although data on body composition are scarce for girls, a notable resemblance exists between the normative 10-year-old boy, as described above, and the reference woman (28% fat, 52.3% water and 19.7% solids). It can be expected that future studies of girls will show that at the time of mature hydration, the female is at about the mature level of total body fat as well. If this suggestion is true, the well-known adolescent changes in female adiposity will prove to be far more a matter of redistribution—especially of the subcutaneous layer—than of absolute increases in the precentage of fat in the body as a whole.

DISCUSSION

In this paper, the hydrometric method has been deliberately overextended. From the evidence, it appears that man shows several typically mammalian growth trends in his body composition. Since direct confirmation of these trends by carcass analyses of children is unlikely in the near future, the substantiation or revision of the present findings will probably have to be done in the living.

Of particular importance is a better established value of k for solids predicted from water in preadolescent children. From such an improvement, better estimations of the age of mature hydration and the growth of fat and solids can be derived.

An approach to the calculation of body fat from body density in children could proceed in a direction parallel to the present study. Boyd ('33) has published a compilation of specific gravities of dead fetuses and living children. Since the fetal data were based on speci-

mens which had never breathed, these determinations are relatively comparable with modern studies of adults, where accurate individual corrections are made for the presence of air in the lungs (Brožek, Henschel, and Keys, '49). For living children and adolescents, however, modern determinations of density are very much to be desired, and no integration of hydrometry and densitometry at these ages will be possible until such data become available.

SUMMARY

A method is presented by which developmental trends in the body composition of children and young women can be effectively described. It is a beginning in the formulation of a system of calculating body composition from body water, density, radiography and skinfolds, comparable to the methods now used for young men (Keys and Brožek, '53).

Allometric equations are calculated between the solid and water content of the fat-free body in human fetuses and neonates, using carcass analyses from the literature. The question of sex differences is explored, and an overall equation finally computed on 59 specimens. This equation is also used to define "reference neonates" of both sexes, containing representative amounts of fat, water and fat-free solids. By considering a typical young American woman as a small, relatively adipose man, it is possible to define a "reference woman" comparable to the "reference man" of Keys and Brožek ('53). This female reference standard has a water content which agrees closely with data in the literature on the hydration of young women.

Since few carcass analyses of human children are known, an attempt was made to work out the postnatal allometry of water and solids in man, by analogy with data on lower mammals. In the pig, and to a much greater degree in the rat, the "solidification" of the fat-free body relative to its accumulation of water proceeds more rapidly postnatally than *in utero*. This postnatal solidification continues allometrically until the mature concentrations of water and solids are attained in the fat-free body. From this time until the animal is fully grown, water and non-fat solids then maintain a constant ratio.

Various calculations for man suggest that the postnatal allometry of water and solids in children continues at the fetal rate, or else with only a slight acceleration as in the pig. If no acceleration takes place, it is possible to estimate the time of mature hydration in man from the

fetal equation without error. If acceleration occurs, however, the fetal equation overestimates the time of mature hydration.

Using the human fetal equation, it was estimated that mature hydration in children is reached at 10½ years in girls and at nearly 14 years in boys. This indicates the possibility of using young adult formulae for computing the fat-free body weight from water whenever hydrometric studies are contemplated on adolescents.

The trends of postnatal body composition in children, as indicated from the fetal equation, are in some respects similar to those of other mammals, and in others unique. At birth, man is a notably adipose organism. *In utero*, he has accumulated non-fat solids (especially bone) rapidly relative to his gain of water, so that his neonatal fat-free body contains less water than that of most lower mammals. He fattens greatly during the suckling period, as do other species.

From weaning to pubescence, man loses little or no fat: the rabbit, cat and pig show quite definite peaks of adiposity at weaning and temporary losses relative to total body weight thereafter. During the preadolescent years, human children undergo gradual relative decreases of total body water and corresponding increases of solids.

In the rabbit and rat, where sex differences have been adequately measured, the female becomes more adipose than the male only after puberty, while in man this difference seems to appear much earlier.

In the rabbit and pig, fat accumulates considerably throughout adolescence, but in the rat this fattening occurs in the earlier part of adolescence, and the animals become less adipose as growth comes to an end. In adolescent girls, the composition of the body changes only slightly, as in the cat, and redistribution rather than accumulation of adipose tissue is suggested by the data. Boys, however, lose much fat and gain considerably in water and solids. This adolescent male pattern is unusual compared with the trends in other known mammals.

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BOOK REVIEWS

Weight Control: A collection of papers presented at the Weight Control Symposium. Edited by ERCEL S. EPPRIGHT, PEARL SWANSON and CARROLD A. IVERSON. viii + 244 pp. The Iowa State College Press, Ames, Iowa, 1955. $2.50.

It is essential for biological survival that every animal should carry about some reserves of food against an emergency. The chemical form is varied. In man the carbohydrate reserve is trivial—at most 500 gm and usually much less. There is a considerable uncertainty as to how much of the protein in the body constitutes a true reserve, but a moiety of the body's protein is undoubtedly labile and this constitutes a true reserve. However, the principal store of food is in the form of fat and the greater part of body fat can be utilized to maintain life during a period of prolonged partial starvation. There is, however, no certainty as to how large this store should be in normal health. It certainly varies a great deal in different individuals. There are now a number of ways of measuring the fat content of a man: of these, the most reliable depends on the fact that fat floats and, if the density of a man is determined by underwater weighing, then the proportion of fat in the body can be calculated. Keys reported that the mean fat content of the people of Minnesota was as follows: young men 14%, young women 25%, middle-aged men 26%, middle aged women 38% of body weight. There are, of course, wide variations about this mean. There is now an accumulation of evidence that an excess of fat is associated with an increased liability to a variety of diseases and a relatively low life expectancy. Excess fat is a biological hazard. There is, however, no indication of what the ideal size of the fat store should be. The size of the actual stores is dependent on the balance between the food eaten and the energy expended in everyday life. Men, of course, must obey the First Law of Thermodynamics, and so a gain in weight must result from a positive energy balance. Normally the appetite mechanism preserves an exact balance and appetite is a good example of a fine "homeostatic mechanism." We know, however, very little about the components of the mechanism. They are in part chemical, in part nervous, and they are also subject to psychological factors. Each of these can be disturbed. There is now good evidence that obesity can arise from psychological, chemical and neurological trauma and, as Mayer points out clearly in

the Symposium, there are several different types of obesity with different etiologies. These have been most clearly defined in the mouse, which is an excellent subject for experimental study, but the human analogues of the various types of mouse obesity probably exist.

In human obesity, attempts at control by reduction in the diet have been for the most part very disappointing. Most fat people find it very difficult to cut down their food intake and, in many, the attempt is associated with real discomfort. Many obese persons do not indeed eat in excess of the generally acepted physiological standards. Their obesity results not so much from over-eating but from under-exercising. Swanson, after reporting that many women appeared to be fat on a daily intake of 1750 Calories or even less, concluded that their energy expenditure must be very low. Their life must be mainly "sitting around." It is only just beginning to be appreciated that one of the results of "progress" in a civilization is that *Homo sapiens* becomes converted into *Homo sedentarius*. *Homo sedentarius* is far from being a "normal" man. In particular his or her appetite fails to establish a normal control of body fat stores. Again the nature of this failure is not fully understood. But the failure presents one of the greatest challenges to human biology.

The participants in the Iowa colloquium discussed these problems clearly and the account here presented makes a most readable book, which can be recommended to biologists with no special knowledge of the subject. The committee responsible for organizing the colloquium and publishing the proceedings deserves credit for their judgment in selection of speakers. The Iowa State College Press have made an excellent job of the production of the volume.

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Methods for Evaluation of Nutritional Adequacy and Status. Edited by HARRY SPECTOR, MARTIN S. PETERSON, AND T. E. FRIEDEMAN. vii + 313 pp. National Academy of Sciences—National Research Council, Washington, 1954. (no price).

Since nutritional status is an ecologic concept, the subject of nutrition involves persons working in the biological and in social sciences. It is not surprising, therefore, to find in this symposium a wide array of

papers (ranging from essential nutrients, through body composition, to the statistical evaluation of population surveys), presented by a wide variety of investigators and approached from the point of view of diverse fields. In reading the 313 pages, the importance of this type of interchange of information becomes readily apparent.

The approach of the symposium is, in another fashion, justifiably limited. The major interest and concern of the Armed Forces is the young, healthy adult male. The emphasis is then on the problems of methodology in the study of nutrition from their point of view.

Nutrition classically involved the study of nutrients so essential to the diet that their absence induced death or specific disease. Today the approach has matured, and the concept of nutritional status has come to involve also the effect of nutrients on the composition of the organism and the effect of this composition on function. The subject of essential nutrients is well covered in this symposium and includes classical and new discussions on proteins, vitamins and minerals. The topic of physical composition is also covered and will be discussed later in this review.

Function, in the final analysis, determines nutritional adequacy or inadequacy, and yet disregarding frank deficiency states, is a newcomer in the field of nutritional symposia. "Adequacy" unfortunately involves complex matters as productivity, be it economic, intellectual, or procreative, and encompasses even the moral behavior of an individual or a society over a brief time or generations. The Army has less involved interests. Their concern relates to the effect of food on morale, to the ability to perform tasks, to withstand severe stress and to recover promptly from physical or psychologic trauma. The appearance in this symposium of material relating to function should stimulate more workers in the field to include this most fundamental aspect of nutritional adequacy in future studies.

It was in the discussion of body composition that an element of stagnation appeared. The determination of body composition *in vivo*, classically, as is discussed fully in the symposium, assumes constancy of the lean body mass in one form or another. Such constancy is physiologically unlikely even in health. Homeostasis, or the constancy of the *milieu intérieur*, is a goal that the organism attempts to attain by varying its physiologic processes within the parameters tolerated by survival. The resultant inconstancy should be recognized (for instance: Adolph, "Physiological Regulations"), and it is the inconstancy rather

than the constancy that may be meaningful. The assumption of constants, or reference standards, may mask or leave neglected areas equally as important as the relative fatness or leanness of any individual. In growth the concepts of change are most impressive, and the assumption of a constant composition or even density of the lean body mass may have to be discarded. It is unlikely even in the adult that such constancy exists or should be hoped or looked for. It seems to this reviewer that the description of the parameters of body composition and their interactions in normal men, which are described briefly in this symposium, may lead to more important methodology than the more emphasized discussion of the relative merits of a standard or reference body or the assumption of constancy of any single phase of composition or function.

All in all, the symposium is stimulating and readable. It leads one to hope that eventually we will know whether Jack Spratt's dietary digressions were, in the long run, worthwhile. The Armed Forces should be congratulated for stimulating and supporting this form of endeavor.

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Fluid Therapy. By JAMES D. HARDY. 255 pp. Lea and Febiger, Philadelphia, 1954. $5.50.

The Body Fluids. By J. RUSSELL ELKINTON AND T. S. DANOWSKI. vi + 626 pp. Williams and Wilkins, Baltimore, 1955. $10.00.

Connective Tissues. Edited by CHARLES RAGAN. 222 pp. Josiah Macy, Jr. Foundation, New York, 1954. $4.25.

Clinical Disorder of Hydration and Acid-Base Equilibrium. By LOUIS G. WELT. viii + 262 pp. Little, Brown and Co., Boston, 1955. $6.00.

While the interest in the physiological role of water in the animal body began to develop more than 100 years ago, its significance for medicine has been made clear only a few decades ago. In the last quarter century great progress has been made in this field, with every sector of clinical medicine benefiting from the increased knowledge concerning the role of the changes in body hydration in different disease states. Measures aiming to correct the disturbances of water and elec-

trolyte equilibria were developed and "fluid therapy" is today an important tool in every medical or surgical clinic. However, the study of changes of the water content of the body is important also for the biology of the "normal" man.

The books listed above present a good picture of the current status of this field. While the basic physiology is considered, the emphasis is placed on practical therapeutics. *Fluid Therapy* gives the answers to many practical problems in the management of clinical alterations of hydration and electrolyte balance, with special reference to surgical patients. Elkinton and Danowski provide a more comprehensive treatise. Diagnostic and research methods are discussed and the practical procedures of therapy are presented in detail. Welt's volume is a valuable and up to date discussion of the clinical manifestations produced by altered hydration of the human body and of their treatment. The first part, about a third of the book, presents the basic physiologic and physicochemical concepts.

The book on *Connective Tissue* is of a different character than the other 3 volumes and, in keeping with the pattern of the Josiah Macy conferences, it presents a discussion of selected topics. The section on interstitial water and connective tissue by Gaudino will be of interest to those engaged in studies of water metabolism and contains valuable information derived from the author's work.

While the publications dealing with body fluids are apt to stress the clinical (diagnostic and therapeutic) applications, it should be noted that there are several fields of human biology, including the sciences of human nutrition and exercise, studies of growth and development, and gerontology, in which the determination of body water and the analysis of its distribution in the different compartments yields important information on body composition.

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Progress in the physiology of farm animals. Edited by JOHN HAMMOND. Vol. I, vii + 392 + xv pp. Vol. II, 395-740 + xv pp. Butterworths, London, 1954, 1955. 45 s. per volume.

During the past quarter century a large amount of research was done on the nutrition, ecology, growth, behavior (with special reference to grazing and mating), locomotion and reproduction of farm animals.

It is the purpose of the present two volumes, shortly to be followed by the final tome, to provide a review and synthesis of this newer knowledge. Individual chapters represent authoritative summaries of the "bulges" along the advancing front of scientific animal husbandry. Availability of well-defined quantitative criteria of "fitness," together with some other factors (including the opportunity for rigorously controlled longitudinal studies), brings out the importance of work in this area for the human biologist, even though the presence of species differences can not be disregarded any more freely than when the results of studies on small laboratory animals are considered.

In the more strictly experimental biological sciences—in physiology, biochemistry, science of nutrition, experimental pathology—the interaction between animal and human studies is a good deal more intensive than in the studies of growth and development, of body form and composition. It is the contributions in this field that will be considered in greater detail here.

Live-weight growth was treated by R. W. Pomeroy (pp. 395-429). Among factors affecting this variable the author considered the "plane of nutrition," vitamins, sex (genetic differences), hormones, and antibiotics. Surprisingly enough, "very little work has been carried out on the factors that influence life-time performance" (p. 401). Thus the information, badly needed in human biology, on the effects of the rates of growth on longevity is inadequate. However, the studies of Hannson *et al.* (1953) confirm C. M. McCay's earlier work on laboratory animals and indicate that the average length of life of heifers reared on a low plane of nutrition was 95 months compared with 75 months for animals reared on a high plane of nutrition.

Nowhere has it been realized more clearly than in animal husbandry that live weight is an inadequate criterion of "growth" and that it must be supplemented by data on carcass composition. H. Pálsson's long chapter on Conformation and Body Composition (pp. 430-542) will be read with profit and interest by physical anthropologists, human anatomists, and pediatricians concerned with problems of growth. The fact, brought out earlier (p. 214), that external similarities between the fat-storing hump of the camel and the purely muscular thickening in the cervico-thoracic region of the Nilotic (Sanga) cattle are grossly deceptive, should make us pause and evaluate more rigorously the validity of somatoscopic ratings in man.

Methodologically, the single most important advancement in the animal studies was J. Hammond's complete-dissection method (1932)

in which the total body is separated anatomically into its component organs and tissues and the weight of each is recorded, together with data on individual bones of the skeleton. The components are expressed as percentages of total weight or, preferably, are compared with a standard organ or part (such as cannon bones or brain-plus-eyes). Hammond and his students and coworkers (McMeekan, Pálsson, Wallace, etc.) used this technique for a systematic analysis of developmental changes in different anatomical regions and in the major organs and tissues of the body. These changes are the basis for the alterations in the conformation of the animal from birth to maturity. Different tissues attain their maximum growth rate during postnatal period in a definite order (central nervous system, bone, muscle, fat) and body fat is accumulated with age in different depots at different rates.

Of basic importance for the assessment of the concept of a definite, "genetically determined" body build is the fact that the animal's form and body proportions can be controlled within fairly wide limits by changing the plane of nutrition of the growing animal. Thus "different planes of nutrition not only produce animals of greatly different weights at the same age, but also of vastly different conformation and composition" (p. 479). This matter appears so important to the reviewer that he feels compelled to supplement the citation by a concrete example: "In general, cattle reared on a low plane of nutrition retain the juvenile form; they are leggy, narrow and shallow in the body, especially in the hind quarters, with long, large heads, as compared with animals of the same breed, even identical twins, which are reared on a high plane of nutrition. As in sheep, limited nutritive supply largely inhibits the normal development of secondary sexual characters" (p. 498). The principal tissues as well as the various internal organs are affected to different degree by the restriction of nutritive supply, with gradients of increasing retarding effects proportional to the postnatal growth intensity of the tissues.

The only serious limitation of Pálsson's presentation is the omission of reference to the recent advances in the study of body composition in living man and in intact animals, based on the determination of body volume (and body density), partitioning of the total body water, and measurements of optical bone density from roentgenograms serving as an index of mineralization. A closer contact between the students of the structure of farm animals and of man would be advantageous to both.

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The Regulation of Hunger and Appetite. Edited by FRANKLIN HOLLANDER. 114 pp. Annals of the New York Academy of Sciences, Vol. 63, Art. 1, New York, 1955. $3.00.

This publication represents the proceedings of a conference convened by the New York Academy of Sciences in November 1954. The 14 papers are divided into three groups (Regulatory Mechanisms, Disorders of Regulation, and Clinical Aspects) and give a fair representation of the points of view and areas of interest of American scientists engaged in this field of research.

It is quickly apparent that agreement on the definition of the terms "hunger" and "appetite," one of the stated purposes of the conference, was not achieved. Thus Quigley adheres to the classical definitions of Cannon and Carlson, designating hunger as unpleasant and appetite as pleasant sensations. Mayer does not attempt rigid definition but subscribes to the view that hunger and appetite are sensations and feelings whereas the phenomena which the scientist is able to measure are such things as food intake and body weight. Brobeck dispenses with the problem by stating that he uses the terms "'appetite' and 'satiety' in a purely behavioral sense, without prejudice as to their subjective or psychological nature." Janowitz and Hollander state that appetite, defined as the desire to eat, can be measured operationally in terms of the amount of food eaten, thus assuming that appetite is the *sole* determinant of eating behavior. Grossman distinguishes between bodily states, behavioral states and psychic states, and further divides behavioral states into learned and unlearned and psychic states into sensation and affect. Thus he speaks of the bodily state of depletion giving rise to unlearned behavioral activity of feeding reflexes and the sensation of hunger. With the establishment of conditioning hunger sensations evoke the affective state of appetite, desire for food, which is reflected behaviorally in learned appetitive acts. While the problems of definition were not resolved by the conference, there was ample recognition of the necessity for distinguishing between and integrating biochemical events, motor acts and psychic states.

Perhaps the greatest contribution in recent years to the understanding of regulation of food intake is the discovery of the effect of discrete lesions of the hypothalamus. This topic is admirably reviewed by Brobeck who has been a leading worker in this field. His recent discovery of a hypothalamic area, destruction of which causes aphagia, will undoubtedly give further impetus to this active field of investigation.

This collection of papers is an important document for all who are interested in the subject. It offers the viewpoints of physiologists, nutritionists, psychiatrists, and psychologists.

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Roberts' Nutrition Work with Children. By ETHEL AUSTIN MARTIN. xvi + 527 pp. University of Chicago Press, 1954. $7.50.

This is the third edition of a classic book on child nutrition by Lydia J. Roberts, first published in 1927. The book was completely rewritten but its aim remains the same, namely, to present principles and practices relevant for attaining better nutrition in children. Readers of this journal will be more interested in the first part of the book, concerned with the basic understanding of the problems. The second part, valuable in its own right, is devoted to educational procedures.

Clinical, chemical, and dietary methods and the assessment of physical growth are considered, and the extent to which each method alone or in combination with the other measures may be used for characterizing nutritional status are discussed. Some 70 pages are devoted to the problems of growth, including the general character of physical growth, factors which affect growth patterns (sex, size, socio-economic status, secular trends, geographic location, race and nationality, defect and disease, season of the year), measures of physical maturity (especially the comparison of roentgenograms of the hand and the wrist with the Greulich-Pyle standards), and a variety of growth standards (Baldwin-Wood age-height-weight tables, the Wetzel grid, Stuart-Meredith growth norms, and Meredith physical growth record). The review of American growth studies, including important current longitudinal investigations, will be appreciated by many.

The most frequent reasons why a child fails to become well nourished and the possible effects of malnutrition on physical growth, dental caries, the course of disease, the nervous system, mental ability, and emotional stability are examined. A large amount of space is devoted to constructive programs designed to help a child to become and remain well nourished. Among the topics discussed are effective nutrition teaching, the school lunch, and the nutritional teaching aids for school and community programs. Chapter VIII contains a valuable description of activities of national and international organizations dealing with nutrition research and educational programs.

The book is well written and will continue to be useful as a text for the student of nutrition, as a guide in practical nutrition programs, and as a reference book. The bibliographies appended to individual chapters will be welcome by those who are seeking more detailed information on a specific subject.

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Tea: A symposium on the pharmacology and the physiologic and psychologic effects of tea. Edited by HENRY J. KLAUNBERG. 64 pp. The Biological Sciences Foundation, Ltd., Washington, D. C., 1955.

The "proceedings" are thin when measured in reference either to the number of pages or to the added knowledge on the subject. The two papers that report new experimental results are reprints of articles published elsewhere. Nevertheless, both a lover of the brew and students of the many facets of the "biology of tea" will peruse the 8 reports with interest and some profit.

A tea infusion has no practically relevant caloric value, contains no sodium and, as S. O. Waife tells us in the introduction, there is scarcely a therapeutic diet in which tea could not be incorporated with impunity. While jam, sugar, milk and pastries can increase the caloric value and enlarge the range of taste-bud stimuli, it is precisely because of its blandness and nutritional innocence that tea is so useful in medicine.

Tea is a versatile beverage, with a delicate and varied aroma, a "social drink" in the best sense of the word, with a tendency to increase alertness, to relieve fatigue, and to produce a sensation of comfort and cheerfulness without being followed by depression.

While an industrious organic chemist can detect in tea traces of a variety of substances, the methylated xanthines, including caffeine, and the tea-tanins are the most important constituents, even though the volatile oils perhaps should not be neglected. The pharmacological effects of the modest amount of caffeine on the cerebral cortex are importantly reinforced and accentuated by social customs and pleasant associations.

Several authors stress the necessity to study the effects of tea infusion as such, not in terms of the chemical components. It was noted that tea

tannins are not identical with tannic acid and that in a properly brewed tea the disturbing effects of caffeine alone and of tannin alone are not present. Tea has a moderate diuretic effect, increases gastric tone and motility, and shortens gastric emptying time, with iced tea having a more pronounced effect in this regard than hot tea. A shortening of simple and complex reaction time was noted in both immediate tests and delayed tests. The immediate effect, clearly, can not be ascribed to the pharmacological action of caffeine and points to a neglected area of study that may, eventually, substantially increase our understanding of "mental fatigue."

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Third International Congress of Nutrition. 486 pp. Stichting tot Wetenschappelijke Voorlichting op Voedingsgebied, The Hague, 1954. (no price).

What Graham Lusk first called the science of nutrition is relatively a late comer. Nevertheless its achievements during the life span of one generation have been remarkable. As an entity, the science of nutrition is a different thing from the classical disciplines taught in universities, *e.g.* physiology, chemistry or physics. It is not limited by the use of one set of technics (as biochemistry) or a scale of structures (as bacteriology). It covers the organic chemistry of nutrients, enzyme chemistry of vitamin function, biochemistry of interconversion of metabolites, physiology of digestion and of regulations of energy exchange and of metabolism, behavior in relation to food, social and economic aspects of food distribution, production and utilization, legal protection of consumers, and a whole branch of medicine dealing with the deficiency diseases and the part of nutrition in the etiology of degenerative diseases.

All these aspects were touched upon at the third International Congres of Nutrition, held in Amsterdam, September 13th to 17th, 1954. The proceedings of the Congress appeared first in the form of separate articles in the Dutch nutrition journal *Voeding* and have recently been collected in book form. This reviewer participated in the Congress and would like to mention that he never attended a scientific meeting more excellently organized. All participants are in the debt of Professors B. C. P. Jansen, M. van Eekelen, and M. J. L. Dols.

The Congress was essentially centered around three topics: obesity, protein malnutrition, and food additives. The choice of these topics is symptomatic. Protein malnutrition in children is the great nutritional scourge of poor areas and is the greatest preoccupation of the Food and Agriculture Organization and of the Nutrition Section of WHO. At the other end of the scale in the Western world, abundance of food and lack of need for physical work have provided an ideal environment for the development of obesity. Modern technology entails its own risks, not the least of which is the possibility that some of the substances used as antioxidants, preservatives, etc. may be toxic and that some of the pesticides (which are, of course, known to be toxic for at least some living species) may not be completely eliminated.

In addition to the three symposium-like groups of papers, there were presentations on unrelated topics, a number of which were of great interest. Space does not permit to cite them all, but the scope of the Congress is exemplified by three of the outstanding papers dealing with: the psychological aspects of nutrition (with special reference to experimental psychodietetics), nutrition as a factor against addiction, and aspects of nutrition research of special interest to FAO.

The book is attractively printed, easy to read, and has good illustrations.

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BOOK NOTICES

ANDROGENS. By Ralph I. Dorfman and Reginald A. Shipley. xii + 390 pp. John Wiley, New York, 1956. $13.50. The androgenic hormones play an important role in the development of male secondary sex characteristics and the male accessory organs of reproduction as well as in the production of male gametes. In both sexes androgenic substances influence libido and protein anabolism. A prodigious amount of information is summarized in reference to the biochemistry, physiology (incl. growth and behavior) and clinical significance of androgens for the benefit of medical and graduate students, clinicians and research workers.

BIOCHEMISTRY AND THE CENTRAL NERVOUS SYSTEM. By Henry McIlwain. vii + 272 pp. Little, Brown and Co., Boston, 1955. $9.50. A systematic presentation of biochemical studies of the brain, developed from research and from teaching in physiology and in psychological medicine at the University of London. Includes consideration of glutamic acid and metal phenomena, and of vitamins (thiamine, nicotinic acid, B_6, B_{12}, pantothenate, riboflavin) the deficiency of which most prominently affects the central nervous system. Selected lists of references are appended to individual chapters.

BIOCHEMISTRY OF THE DEVELOPING NERVOUS SYSTEM. Edited by H. Waelsch. xvii + 537 pp. Academic Press, New York, 1955. $11.50. The papers constituting these extensive proceedings of the First International Neurochemical symposium, held at Magdalen College, Oxford, July 13-17, 1954, are centered around the following topics: morphological and functional ontogeny, chemical composition, blood-brain barrier, metabolism of the developing brain, enzymatic differentiation, cellular chemistry, genetics, and hormonal factors. Discussions of individual presentations, a large amount of pictorial material in the text, and a subject and author index enhance the value of this vivid portrait of an active segment of neurochemistry.

CLASSIFICATION FOR MEDICAL AND VETERINARY LIBRARIES. By Cyril C. Barnard. viii + 279 pp. H. K. Lewis and Co., London, 1955. 4.4 s. The classificatory system, using letter combinations rather than numbers, was originally devised for the London School of Hygiene and Tropical medicine. In the second edition the notation was adapted for the use in general medical libraries. Realizing that it is hard to satisfy all customers, it may be noted that physical anthropology is placed in Class Z (Geography, anthropology, sociology), while works on growth and forms are put into Class B Natural Science), division J (Biology), subdivision M. Should roller skates be issued together with the stack permit in libraries using Mr. Barnard's system?

THE DYNAMIC EQUILIBRIUM OF BODY PROTEINS. By George H. Whipple. vi + 68 pp. Charles C. Thomas, Springfield, Ill., 1955. $3.25. A review of information on the interchange between the proteins in circulation, in extra-cellular fluid, in the cells, and in the reserve stores, with special

reference to results obtained in the course of some 30 years of research at the Department of Pathology, University of Rochester.

THE FUNDAMENTALS OF X-RAY AND RADIUM PHYSICS. By Joseph Selman. xii + 340 pp. Charles C. Thomas, Springfield, Ill., 1954. $8.50. Based on materials used in the instruction of student X-ray technicians, the book covers relevant theoretical and practical aspects of radiological physics. It will be found useful by individuals who need an elementary introduction to the subject.

GRAPHIQUES DE CROISSANCE DES ÉLÈVES DES ÉCOLES DE BRUXELLES. Institut Royal des Sciences Naturelles de Belgique. (no date) Instructions (6 pp.), in French and in Flemish, concerning the use of graphs for the evaluation of growth in reference to skeletal size (height), body weight, and musculature (estimated from a sum of the circumferences of the upper arm, with the forearm extended and flexed, and calf, not corrected for subcutaneous adipose tissue). Ages 6 to 15, males and females. In height-weight graphs the zones including the middle 70, next 25, 4 and 1% are indicated by eliptoid curves. Average values for adjacent ages are indicated.

HANDBOOK OF VITAL STATISTICS. Statistical Office of the United Nations. iv + 258 pp. United Nations, New York, 1955, $2.50. Information on births and deaths, on marriages and divorces, is required as a basis for developing more effective socio-economic policies and represents an important tool of epidemiological research. The purpose of the Handbook is "to explore current practices, to make conveniently available recommended statistical standards, and to present uniform concepts, definitions, and procedures upon which development of national vital statistics and the improvement of their international comparability may be based."

THE PHYSIOLOGY OF DOMESTIC ANIMALS. By H. H. Dukes. xii + 1020 pp. Cornell Univ. Press, Ithaca, New York, 1955. $9.75. A standard textbook in the field of animal physiology, designed for students of veterinary medicine and animal husbandry. The volume, now in its 7th edition, underwent an extensive revision and was supplemented with several new chapters, including M. R. Kare's chapter in which fluid compartments of the body are briefly discussed. Six pages are devoted to growth.

PHYSIOLOGY AND PATHOLOGY OF INFANT NUTRITION. By L. F. Meyer and Erich Nassau. ix + 533 pp. Charles C. Thomas, Springfield, Ill., 1955. $11.50. Intended for the medical student and the practicing physician, the book contains a section on physical growth (pp. 6-41), including the development of adipose tissues (pp. 32-37), a chapter on the characterization of the nutritional state (eutrophy, dystrophy, atrophy), and on constitution and nutrition.

PRESENT KNOWLEDGE IN NUTRITION. By the Editorial Staff and Advisory Board, Nutrition Reviews. 130 pp. The Nutrition Foundation, New York, 1956. The second revised edition of a useful monograph based on articles previously published in the journal *Nutrition Reviews*, focussed on the major organic foodstuffs, minerals, and vitamins.

RADIOSOTOPE CONFERENCE, 1954. Vol. I. Edited by J. E. Johnston. xi + 418 pp.

Academic Press, New York, 1954. $10.80. The first volume of the proceedings of a conference sponsored by the Atomic Research Establishment, Harwell, England, and held in July 1954, contains 46 papers devoted to medical and physiological applications (therapy, diagnosis, animal physiology and pathology, biochemistry, plant nutrition). Subject index is lacking. The use of radioisotope techniques for the study of body composition *in vivo* was not discussed.

RADIOISTOPES IN BIOLOGY AND AGRICULTURE. By C. L. Comar. xiii + 481 pp. McGraw-Hill Book Co., New York, 1955. $9.00. The publication, addressed to the student and the investigator, summarizes in one volume the basic information needed in radioisotope tracer studies. The more general aspects of tracer methodology, properties and usage of individual radioisotopes, and specific procedures (autoradiography, paper chromatography, ion exchange, radioactivation analysis) are presented in turn. Several appendixes, including a glossary, increase the practical value of this book. Exploration of the labyrinths of intermediary metabolism, autoradiographic study of deposition of Ca^{45} in reference to bony structure, and radiocarbon dating indicate the wide range of applicability of radioisotope techniques.

A SHORT HISTORY OF MEDICINE. By Erwin H. Ackerknecht. xviii + 258 pp. The Ronald Press Co., New York, 1955. $4.50. A readable presentation of a complex subject. Last 100 pages are devoted to the developments since the beginning of the 19th century. Throughout, the author makes a conscious effort not to fall into the pattern of purely cataloguing names and events. Separate chapters are devoted to medicine in the United States prior to 1900 and to the main trends in the 20th century. The list of selected readings emphasizes reprints and translations of medical classics.

SOCIETY AND MEDICINE. The New York Academy of Medicine. Edited by Iago Galdston. International Universities Press, New York, 1955. $3.00. A collection of essays on a variety of subjects, including the biology of ethics R. W. Gerard), natural history of neurotic behavior (H. S. Liddell), enviroment and heredity (T. H. Ingalls), and effects of food on health (R. M. Wilder).

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